TAAM Best Practices Guidelines

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Abstract

At the request of the Federal Aviation Administration (FAA), The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) has assembled a collection of recommended practices for applying the Total Airspace and Airspace Modeller (TAAM) to aviation system simulations. Candidates for TAAM best practices were solicited from experienced TAAM users both in and out of CAASD. These practices are described in the context of project planning and execution.

KEYWORDS: Aviation, Best Practices, Modeling, Simulation, Total Airspace and Airport Modeller (TAAM)

Acknowledgments

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Section 1

Overview

1.1 Purpose of the TAAM Best Practices Guidelines

The Total Airspace and Airspace Modeller (TAAM) is a complex and sophisticated tool that can be used to increase insight for many types of airport and airspace problem. TAAM has been used worldwide by civil aviation authorities, airlines, and airports for more than a decade, and it has been used by the U.S. Federal Aviation Administration (FAA) for airspace analysis since 1998.

TAAM is a flexible tool, and there are many different ways to approach a TAAM modeling problem. Often an analyst will apply a trial-and-error approach when asked to exercise an unfamiliar TAAM capability. Even very experienced analysts may be asked to model novel situations, which may require an exploratory approach. However, some techniques and combinations of techniques have been found to contribute to successful TAAM studies; other techniques are to be avoided. These techniques have been passed informally among TAAM users over the years, but not documented.

The FAA suggested that lessons learned and best practices be formally documented and made available to the entire TAAM community. Such a document would benefit new users, improve efficiency or quality for current users, and, over time, increase consistency and reusability among models. The novice TAAM user could use a best practices document to bridge the gap between having an elementary knowledge of how TAAM operates to being able to apply TAAM with skill and judgement to a variety of aviation problems. Because TAAM contains more capabilities than are likely to be mastered by any single analyst, the document could also assist more experienced users when they face an unfamiliar aspect of TAAM.

The FAA asked The MITRE Corporation's Center for Advanced Aviation Systems Development (CAASD) to work with the TAAM user community to draft the first version of *TAAM Best Practices Guidelines*. This document is an assembly of tips, suggestions, checklists and warnings collected from the experience of many TAAM users, including CAASD's own experience in FAA airspace studies. It is expected that the TAAM community will modify and supplement this document to reflect new modeling experiences and changes to TAAM itself.

1.2 Intended Audience

These guidelines assume that you, the reader, have completed the TAAM basic training or are familiar with the TAAM's contents and execution. For particulars of how to log in to TAAM and run a simulation, please refer to the following documents published by The Preston Group (TPG):

- TAAM Plus Reference Manual

- TAAM Practical Guide

- TAAM Plus Capabilities and Applications

- TAAM Functional and Conceptual Overview

Section 8, Reviewing a TAAM Study, is addressed to reviewers who may or may not have previous acquaintance with TAAM.

1.3 Structure of the TAAM Best Practices Guidelines

Section 2, **The TAAM Project**, takes an overview of a generic TAAM project, moving step by step from the initial project definition until the presentation of final study results. Section 2 presents an outline each of the tasks likely to occur in a TAAM project, describes the dependencies among these tasks, and highlights the critical tasks that can become project bottlenecks.

Section 3, **Working with TAAM Input Data**, discusses the many types of data that are input to a TAAM simulation. Some of these data, such as a flight schedule, apply to every TAAM simulation but others apply only in particular cases, such as when the TAAM simulation represents detailed ground movements.

Section 4, **How to Build, Verify, and Validate the TAAM Simulation**, addresses the task of constructing an aviation simulation using TAAM and validating that simulation.

Section 5, **How to Refine the TAAM Simulation**, covers advanced topics and trouble-shooting techniques for building and executing an aviation simulation with TAAM.

Section 6, **Working with TAAM Output Reports**, gives suggestions on how to read and interpret the TAAM output files.

Section 7 **Presenting the Results of a TAAM Study**, offers check lists for what to include in a presentation or report describing a TAAM study.

Section 8, **Reviewing a TAAM Study**, gives a list of questions about the overall study. These questions could be used by a reviewer, or by a TAAM developer preparing for a review.

Appendix A, **An Overview of Fast Time Simulation**, gives an introduction to the concepts and vocabulary of simulation.

Appendix B, **Developing Flight Schedules** presents an example of how to develop TAAM flight schedules from external data sources.

If you are managing a TAAM project, read at least Sections 2, 6, and 7. If you are a developer, read Section 2 followed by 3, 4, 5, 6, and 7. Section 5 contains advanced topics and may be omitted on a first reading. If your main interest is reviewing a TAAM project, read Section 8.

1.4 TAAM Version

Unless otherwise noted, all the recommendations in this document apply to TAAM Plus Version 1.1.2.

Section 2

The TAAM Project

This section examines a generic TAAM project from two points of view. Section 2.1 gives an overview of vital knowledge you ought to have before beginning to manage a TAAM project. Section 2.2 presents the sequence of tasks that compose most TAAM projects and discusses the task dependencies. Certain tasks can be particularly challenging and can become project bottlenecks. These tasks are highlighted as candidates for early intervention if progress is not going as expected.

2.1 TAAM Study Design

2.1.1 Study Design Statement

The purpose of the study design statement is to document the expectations of the study for both the sponsor and the analyst. This statement should include the study's objective, metrics, assumptions, and the form of the final product, all subject to updating in the course of the study.

Defining the objective of a TAAM study can be a difficult task in itself. The purpose of any simulation is to gain a better understanding about the system being simulated. Because TAAM contains so many simulation features, there is always a certain danger of building a model that contains many details, but little content. You can reduce this danger by beginning each TAAM study with a "study design statement" that includes a detailed description of the study's objective.

The objective of a TAAM study should have two key characteristics: first, it should affect a decision to be made about an aviation system, and second, it should be defined in terms of the values of specified metrics. For example, an airport authority deciding whether to build a new high-speed runway exit might be interested in the time it takes for an aircraft to taxi from the runway to its gate. Here the decision is to build the exit or not and the metric of interest is the taxi times.

A study design statement such as "create a simulation of ground traffic at airport X" does not describe an appropriate objective because it contains neither decision nor metrics that would have a bearing on that decision. If your clients are not familiar with simulation studies, they may need some help framing an appropriate objective. Part of your preparation for the kickoff meeting with the client should be to develop a list of candidate study design statements.

2.1.2 Base Case

A TAAM base case is the simulation model of the operation of the air traffic system[1] being studied with which the study alternatives are compared. The base case may represent either current operations or a hypothetical situation.

You may need to construct more than one TAAM scenario to cover the base case. For example, if you have more than one set of airport runway configuration (East/West flow, North/South flow) or more than one weather condition (Instrument Meteorological Conditions [IMC], Visual Meteorological Conditions [VMC]), or more than one level of traffic (typical weekday, high traffic day) you will need a separate scenario for each set of conditions. Other reasons for needing to build more than one TAAM scenario to cover a base case might entail differences in airspace sectorization or rules for aircraft separation. Because each scenario requires you to build a separate TAAM "project", you will want to define your study using as small a number of scenarios as possible.

Your goal during the development of the base case is to calibrate each scenario for the specific study until the simulation output is consistent with the actual or intended target system. (For a discussion on calibrating or validating your model, see Section 4, "How to Build, Verify and Validate the TAAM Simulation".) You measure consistency using predefined metrics (such as airport throughput, departure/arrival delays, and sector load) and through visual inspection by domain experts. You may need to modify the TAAM simulation input to achieve satisfactory consistency. For example, you may need to adjust aircraft performance data to reflect the main airport's elevation or specific performance for the dominant carrier, or specific waivers for in-trail separation. It is a good practice to get feedback from the study stakeholders on the performance of the scenarios in your base case before proceeding to build the alternative cases to explore the "what-if?" situations.

2.1.3 Alternative Cases

The purpose of the alternative cases is to draw conclusions for your study by comparing the output from a base case scenario to the corresponding alternative case scenario. You build each alternative by modifying one or more of the model settings in the base case. The difference between the base and alternative case may entail a change in airport configuration, air traffic control procedures, or flight restrictions. Note that you will usually need to define as many scenarios for each alternative case as you needed to define for the base case. So if you defined four scenarios for your base case; for example, East flow and West flow, each

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[1] An air traffic system is a generic name for the airspace+airport(s) being modeled. It could be represented by a cluster of airports, their terminal airspace and all traffic in, out and through this terminal area, or by the area control airspace and all its through traffic, or by a group of area control centers, or eventually, by an entire air navigation system such as the United States National Airspace System (NAS).

one with and without a restriction, then you will need to build four times as many TAAM projects as you have alternative cases. So in addition to defining the base case using as few scenarios as possible, you want to examine the smallest possible number of alternative cases to keep the amount of effort required for the study reasonable.

It is important to ensure that the alternative cases remain consistent with the base case except for the features that differentiate the alternatives from the base. The accuracy of the study results can be compromised if the base and alternative cases differ in other respects. It is good practice to use a common development path for the common features of the base and alternative cases.

Here are some examples of scenarios for alternative cases:

- **Traffic level**. In this scenario, you simulate the future situation by increasing the traffic to a new level while keeping all the other settings the same. You would use this comparison to model a situation where the airport layout and procedures are the same, but the traffic demand is increasing.

- **Aircraft type or equipage mix**. A change in the aircraft type mix in a scenario can mean changes in performance and consequent changes in throughput or delay. You may want to examine the effects of differences in navigation equipage which would cause some aircraft to be confined to, or restricted from certain routes, altitudes, or airspace sectors. If you are simulating extreme weather conditions, some aircraft types may not be able to land at a particular airport, changing arrival and departure rates.

- **En route separation**. If you want to examine the effects of reducing en route separation standards (either lateral or vertical separation minima), have your base and alternative case each represent a particular value of that standard.

- **Airport configuration**. If you want to estimate the impact that a new runway will have on the airport and the surrounding airspace, apply the same traffic to the original and modified airport layout. You can use the same technique to show the impact of a having a runway closed for maintenance.

2.1.4 Assumptions

Develop a detailed statement of all the assumptions underlying the study and be prepared to maintain this statement as the study definition takes shape. An accurate and complete set of assumptions is critical to a successful TAAM study. The assumptions address many aspects applying to a TAAM study, such as:

- **Study scope**. The geographic boundaries; the level of detail used in modeling ground, terminal, or en route operations; how many airports to model at what level of detail; which configurations will be examined.

- **Runway use**. Any static or dynamic preferences or restrictions; any runway dependencies.

- **Gates, aprons, and parking positions**. Any static or dynamic preferences; restrictions by airline, type of user, type of equipment.

- **Taxiways**. Any static or dynamic preferences or restrictions concerning direction of travel; speed of travel (including high-speed runway exits); lineup for departure; runway crossings.

- **Terminal airspace operation**. Arrival and departure patterns; preferences and restrictions; dynamic changes and patterns.

- **En route airspace**. Miles-In-Trail (MIT) restrictions; altitude restrictions; effects of dynamic restricted airspace (such as Special Use Airspace); conflict resolution rules.

- **Traffic**. City pairs and routes; timing; future projections; fleet mix.

- **Weather conditions**. VFR or IFR conditions, weather constant or varying throughout the simulated time.

2.1.5 Metrics

The study metrics are a set of quantifiable output elements, such as airport delay, airport throughput, flight time, taxi time, and number of conflicts. You choose the study metrics so that they accurately represent the difference between the base and alternative cases and support the study objective. Figure 2-1, Metrics, shows the relationship between the metrics and their indications. Some of the metrics listed in Figure 2-1 can be computed directly from TAAM output.

Note that it is often necessary to combine several metrics to draw a conclusion. For example, consider an airport study where a new runway is proposed to be built parallel to the existing runway. Because of terrain and other constraints, the new runway is planned to be placed more than 5400 ft apart from the existing one. A simulation of the dual runway configuration shows reduced delays. At an airport with heavy traffic, the benefit of the reduced delay could be very large. But if the traffic levels at this airport are relatively low then the higher costs due to longer taxi times to/from the new runway could conceivably outweigh the benefits from lower delays. Therefore most of the airport's users would not incur a benefit from the new runway. However if a major courier company was planning to build a hub at that airport, and had a requirement to get all its departures out within a certain time window, the presence of parallel runways could be critical to the planning decision.

Indicators   **Metrics**

| System Safety |

1. Convergence Pairs
2. Average Time to Converge

| System Delay/Efficiency | | En Route Delay |
                                | Arrival Delay |
                                | Departure De lay |
                                | Ground Delays |
                                | User Cost |

3. Average En Route Flight Time
4. Average Arrival Flight Time
5. Average Departure Flight time
6. Average Taxi-Out Time
7. Average Taxi-In Time
8. Average Fuel Usage

| System Flexibility | | En Route Distance Flown |
                          | Arrival Distance Flown |
                          | Departure Distance Flown |
                          | Altitude Flexibility |

9. Average En Route Flight Distance
10. Average Arrival Flight Distance
11. Average Departure Flight Distance
12. Average Climb Time
13. Average Descent Time

| System Predictability | | En Route Time Predictability |
                             | Arrival Time Predictability |
                             | Departure Time Predictability |
                             | Ground Time Predictability |

14. En Route Time Variability
15. Arrival Time Variability
16. Departure Time Variability
17. Taxi-In Time Variability
18. Taxi-Out Time Variability

| User Access | | Civilian SUA Usage |
                   | ATC Surveillance & Comm |

19. Average Civilian Special Use Airspace Flights
20. ATC Surveillance
21. ATC Communication

| System Productivity | | Sector Productivity |
                           | Aircraft Convergence Information |
                           | Controller Coordination |

22. Sector Throughput
23. Average Time in Sector
24. Number of Aircraft Entering Sector
25. Number of Aircraft Leaving Sector
26. Aircraft Convergence Position
27. Closest Point of Approach
28. Average Controller Coordination Actions

| System Capacity | | Airport capacity |

29. Airport Arrival Utilization
30. Airport Departure Utilization

| Environmental Impact |

31. Day-Night Average Sound Level

Figure 2-1. Metrics

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2.1.6 Managing Risks

However hard you try to establish and maintain a set of stable assumptions and objectives for a TAAM study, it frequently happens that the client will modify the existing requirements or add new ones after the study is underway. This is the problem notoriously called "study creep" or "moving goal posts". One cause of instability might be that erroneous assumptions have been built into the study in early stages and have not been identified until time is running short. While the risk of this problem can never be eliminated, the following actions can mitigate the risk:

- **Be realistic about what TAAM can and cannot do**. Before the study begins, educate the client about TAAM's capabilities and deficiencies, and what can be realistically achieved within the allocated time and budget. This is discussed in more detail in Section 2.1.7.

- **Perform experiments before committing to use unfamiliar TAAM features**. If an aspect of your study appears to depend on using a capability in TAAM that is unfamiliar to the analytical team, build a prototype simulation using that capability to get the relevant experience quickly. You should be able to demonstrate that you can prepare the relevant input, perform appropriate processing in TAAM, and produce useable output without putting an unreasonable burden on the team.

- **Check the study requirements and assumptions for traps**. A small change of terminology can transform a TAAM study from one that is feasible to one that is nearly impossible. Study the simulation assumptions defined up front in detail and in a clear, unambiguous manner. Communicate any contradictions or other problems with the assumptions to the client as soon as they are identified, to allow maximum time for fixes.

- **Stay current with TAAM capabilities**. Make sure that the people making the decisions about the project scope are not only trained in TAAM, but also up-to-date on its current functionality and limitations.

- **Report any TAAM problems to TPG promptly**. Sometimes you will encounter a software problem with TAAM. Whenever you suspect that unexpected behavior in TAAM might be caused by problems in the software, design an experiment to isolate the suspected feature, possibly with reduced air traffic input. Report any such problems to TPG immediately. If it is a known problem, TPG staff may already have devised a patch or a "work-around". If it is a new problem, TPG may be able to help you identify and fix that problem in less time than you might have spent otherwise.

- **Control the budget**. Exercise disciplined budget control, with weekly or bi-weekly reports on the amount of work performed, money spent, funds remaining etc.

- **Make a conservative schedule**. Build contingency timing and funding into the budget leaving some room for the team to maneuver in case conditions change following the kick-off meeting.

2.1.7 Client Education

If some or all members of your client audience are new to TAAM, or new to simulation modeling in general, and there is time available, take the opportunity to educate the audience on these subjects. For some background material, see Appendix A, "An Overview of Fast Time Simulation".

The points to make during this short "educational" talk include:

- TAAM is a "fast-time" "gate-to-gate" simulator. What is "fast-time" and what is "gate-to-gate"? Explain and, if possible, demonstrate what these mean.

- TAAM is a powerful tool but it is not an optimizer – it will not run the traffic in the best possible way, but rather, it will help an intelligent operator find an optimal solution or assess alternatives quickly.

- Simulation is not the same as playback, and TAAM uses a rule base and flight plans as input rather than actual gate allocation or flight tracks more typical for a playback tool. The value of a simulation is that it helps us have an insight into the unknown such as the impact of new infrastructure projects, traffic growth, closures, airspace redesign and so on.

- While TAAM is a very powerful model, it does have its limitations, and it is very important to take them into account.

- The simulation scenario is a simplification of real world phenomena. We don't know, or can't know, or don't want to be dealing with many "small" things, such as technical problems delaying aircraft departures, passengers being late, different air traffic controller skills, minor weather variations, small weight or performance variations among the aircraft fleet etc.

- The labels of the TAAM output metrics may be confusing. For example, there is a difference between what is called a delay in TAAM and the "official" FAA definition of a delay. Explain the differences and be prepared to keep explaining them.

- Some tolerances between the TAAM output and real data are permissible and reasonable. Because a simulation is not a playback of real operation, an exact match is unlikely. Sometimes, the study timeline and budget dictate how wide or how narrow the tolerances will be.

2.2 Tasks in a TAAM Study

Although no two TAAM studies proceed in exactly the same way, they have enough common features that it is possible to draw a map of tasks in a generic TAAM study with their dependencies. This map is shown on Figure 2-2, "Task Flow for a TAAM Study", which appears as a three-page foldout at the end of this document. The process of a TAAM study divides into four approximate phases:

- **Groundwork**. The first phase, goes from Task 1, "Identify Resources" until Task 4, "Hold External Project Kickoff Meeting" and covers the preparation to define and perform a TAAM study. During this time, the analytical team begins learning about the problem the client is facing, and the client begins learning about the possibilities of simulation and TAAM. Ideally, in this time, the client and the analytical team will begin working together as an overall study team where the groups take on different responsibilities to address the same problems. The outcome of this phase should be the initial statement of the problem that the simulation will address and its associated metrics.

- **Prototype**. The second phase goes from Task 5, "Develop Approach" to Task 13, "Reassess Study". This phase covers the initial data collection and construction of the many TAAM input data files in Task 7, "Build First-Level Input Files" and Task 8, "Build Second-Level Input Files. These are divided into subtasks some of which have the potential to hold up overall progress and are highlighted in Figure 2-2[*], "Task Flow for a TAAM Study" as danger spots or bottlenecks. The outcome of this phase is for the analytical team to be able to demonstrate (formally or informally) that they will be able to build TAAM simulations to address all the characteristics contained in the initial problem statement, in which case the work in Task 13 is merely to confirm the problem statement drafted in the groundwork phase But if the model developers have identified obstacles to this goal, then in Task 13 the entire study team works to redefine the problem statement in the light of more complete information.

- **Refinement and Validation**. The third phase is where the models built in the prototype phase are developed into more detailed and complete models of the base and alternative cases being studied. This phase goes from Task 14, "First Development Cycle", through Task 20 "Conclude Simulation Development". The outcome of this phase is an agreement among the study team members that the models built to represent the base and alternative cases described in the problem statement are *valid*, that is, the models represent the problem sufficiently well that their output is meaningful. This phase is divided into two parts, each consisting of an iterative model development followed by a validation exercise. While in theory the

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[*] Figure 2-2, "Task Flow for a TAAM Study" is a three-page foldout at the end of this document.

second part may not be required, in practice it is required so frequently that two validation cycles should be included in the study plan from the beginning.

- **Finishing**. The final phase is where the results of executing the validated simulation are delivered to the client. This phase includes the final simulation execution and subsequent derivation of the metrics defined in the problem statement. The project deliverable may contain a live briefing, production of a paper report, production of data files, or all three.

Although estimating the time to perform each task is critical for project management, it has not been practical to include estimates of time allowances for each task. There is great variation in the size of projects using TAAM as well as variation in the size and experience level of the study team. The time required to accomplish all twenty-four tasks can range from several weeks to many months and must be determined afresh for each project.

A few of the tasks illustrated in Figure 2-2, "Task Flow for a TAAM Study" at the end of this document, have the potential to become serious project bottlenecks. These tasks are shown in bold type and labeled with three asterisks.

2.2.1 Identify Resources (Task 1)

Begin with an inventory of your available resources. Every TAAM study requires hardware and software resources and an analytical team with a variety of skills. You do not need all of these to be available at the beginning of the project, but if you have resource deficiencies, you should make plans for remedies as soon as possible. The descriptions below cover only a minimum of resources for a generic TAAM study – any particular study may well require additional resources.

2.2.1.1 The Team (Box 1a)

The ideal TAAM project team consists of one or more staff who, as a group, possess the skills to perform the following roles:

- **Leading the project**. Acts as the main point of contact with the project sponsor and guides the project team throughout the project phases. Main tasks include project scheduling, organizing resources, allocating tasks, generating briefings and reports, presenting project status and study results to the sponsor. Should understand the sponsor needs, crisis management, and motivating the project team to commit to deliver.

- **Developing the TAAM model**. Is familiar with the mechanism of inputting data into TAAM and conducting the simulation. Is familiar with the domain of the simulation (airport, TMA, or en route environment). Main tasks include interpreting the information collected from the study site and converting it into simulation settings and rules. This staff is proficient in the process of running a simulation, interpreting

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the results, and modifying the settings and rules to achieve an appropriate representation of the problem being modeled.

- **Managing the data**. Is familiar with the process of preparing the data that is input to TAAM and extracting results from TAAM output. This staff is familiar with the basic UNIX commands for navigating the TAAM data directory structure and the TAAM data formats. The data manager can set up a project file and prepare the necessary input data sets. This preparation may require data conversion from other data sources.

- **Providing operational expertise**. Is familiar with the Air Traffic Control (ATC) environment. Ideally this staff has an operational ATC experience (controller, ATC technology, pilot, airline personnel) and is capable of interpreting the simulation requirements for the team and verifying the model during the development.

- **Building software tools**. Sometimes a TAAM project requires software tools to automate an elaborate data conversion for input or data reduction for output. In such a case, the TAAM team should include staff with the skills to write software for parsing and reformatting data, or for calculating necessary metrics from the available output data.

- **System administration**. Can take responsibility for the logistics and performance of hardware, software, and peripherals necessary to conduct a TAAM study. This staff is familiar with those resources and be able to trouble-shoot so that the study does not have to be interrupted. This staff is also responsible for installing TAAM version updates and maintaining the TAAM license manager.

2.2.1.2 Hardware and Software Resources (Box 1b)

- **TAAM Workstation**. Each TAAM simulation developer should have ready access to a computer terminal capable of running TAAM. That terminal can be a workstation that is the TAAM host, a workstation connected to the TAAM host over a network, or a PC with a login capability to log in remotely to the TAAM host over the network.

If you have more TAAM licenses than TAAM simulation developers who use the licenses at any one time, then you will not be able to make full use of your licenses. If you have more active simulation developers than TAAM licenses, progress on your study may slow down while developers queue for an opportunity to prepare data or execute simulations.

- **TAAM Software**. The TAAM application consists of several modules and a license manager. The license manager controls the number of copies of each module that can be used simultaneously. TPG issues periodic updates to the modules. If TPG issues an update while a project is incomplete, it is very important to make sure that all modules used in the project are from the same version. Depending on how far the project has advanced, the effort of converting a project to a new TAAM version may or may not be worth while.

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- **Support Software and Hardware**. You will need supplementary software to prepare input data and output reports. At a minimum, you will want to have text editor, spreadsheet, and database applications. Because of the size and complexity of TAAM input and output, you may want to add additional data processing tools, either Commercial Off The Shelf (COTS) or developed in-house. You will need access to a high-quality color printer for producing reports.

- **Internet Access**. Each TAAM developer should have access to electronic mail and the World Wide Web. These are the channels TPG uses to publish updated information about TAAM and to communicate with the TAAM users. They are also used for exchanging technical information among TAAM users worldwide.

2.2.2 Hold Internal Kickoff Meeting (Task 2)

Discuss the known goals for this project. Make plans to remedy any resource deficiencies identified in the previous task. Determine what information needs to be collected as preparation for the kickoff meeting with the client.

2.2.3 Investigate Study Background (Task 3)

This task constitutes the preparation for the external kickoff meeting with the client. That meeting can be very productive if the analytical team already has some acquaintance with the physical, procedural, and political issues affecting the study.

2.2.3.1 Research Physical Infrastructure

Become conversant in the physical characteristics of the study area including airports, runways, typical weather conditions, primary runway configurations, arrival and departure fixes.

2.2.3.2 Research Procedural Issues

Become conversant on airport capacity, airspace restrictions, ATC and user concerns, and the issues that restrict capacity or contribute to delay in the study area.

2.2.3.3 Research Stakeholders

The study stakeholders include:

- Your direct client

- The client's affiliates or other departments in the client's organization

- Organizations or groups affected by the study:
    - The airport authority

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- Local ATC facilities (tower, terminal, or area control center)

- Controller or pilot unions

- Citizen's groups in studies that have environmental impact

- City authorities or other government officials or auditors

- Engineering and consulting firms working with the given airport or airline

These groups may have diverse, often conflicting interests, and not all of them may initially support the study. You want to identify stakeholders and include them as early in the project as possible so that you can be aware of their concerns and have an opportunity to educate them about the capabilities and limitations of fast-time simulation in general (see Appendix A for a brief exposition) and of TAAM in particular (see Section 2.1.7).

2.2.4 Hold Kickoff Meeting with Client (Task 4)

The entire study team, that is, all the people who will work together on the project, both clients and the analytical team members, should attend the kickoff meeting. This meeting is an opportunity for everyone to get introduced and begin to establish a consensus on what the study is meant to accomplish.

Present a briefing (and perhaps also a demonstration) about data requirements, metrics, and TAAM's capabilities and limitations as applied to the technical issues involved in the study. Present your interpretation of the issues that you investigated in Task 3, "Investigate Study Background" and be prepared to assimilate new information and opinions. Work with the client to determine initial definitions of scope, metrics and the project timelines, but make it clear that these are subject to change based on unknowns in modeling effort. Discuss the basic study assumptions and an approach for developing the required input data (described in Section 3, Working with TAAM Input Data).

Following the briefing, the study team should:

- Reach agreement on the definition of the study objective.

- Discuss the basic study assumptions that will support the study objective.

- Discuss an approach for developing the required input data.

- Reach agreement on the definition of the base case and alternatives for this study.

- Reach agreement on TAAM simulation outputs, metrics and tolerances. This is a good place to remind everybody that some values output from TAAM (such as delay) have a slightly different definition from the items in the operational log with the same names.

- Reach agreement on the initial study timeline and meeting schedule, consistent with the project cost. How long will it take to build the base case? How long before the first milestone meeting? Will there be interim products and when should they be delivered? What details should be included in each product? What is the definition of the final product? When is the final presentation expected?

2.2.5 Develop Approach (Task 5)

This task has two parts, both connected with documentation. The first part is to begin writing the final report, even though at this stage it is mainly an outline. The first piece of report content you can develop here is the study design statement that describes the essence of the study. The second part is to establish your study log by defining and recording project, file naming, and configuration management conventions.

2.2.5.1 Develop Study Design Statement (Box 5a)

You can and should begin writing the study final report right after the kick-off meeting. Even at this early stage, your study report can document the characterization of the problem, and study assumptions concerning, for example, how the airspace is managed, typical traffic flows, and weather conditions. You should also delineate areas the study will not address.

The design statement may change as you make progress towards defining the model and understanding what details are required to achieve the desired output. After the kick-off, when the study is initiated, you can update the report to include any updates to the initial material, and can include identification of the metrics the proposed change will impact, and proposed alternatives. Add the base case calibration and validation section as soon as these activities are complete. This timely report preparation will pay for itself at the end of the study. When the all the TAAM runs for the base case and alternatives are complete, then you can add an overall analysis of the simulation results, and conclusions about the impact of each of the alternatives.

2.2.5.2 Coordinate Project Conventions (Box 5b)

Establish a study log where you can record all the relevant history of the simulations and associated files. This can be a physical or electronic document, but make sure that everyone working on simulation development has easy access to read it and add to it. Decide on an initial set of project and file-naming conventions and record these in the log. Remember that at this time in the study, you are unlikely to have complete knowledge of all the components – they may well grow and contract – so select conventions that allow room for growth.

Although formal configuration management techniques may not be appropriate for all studies, it is a very good idea to define (and write into the study log) the practices you will use to minimize the risks of data contamination and loss and to ensure that critical parts of the study can be replicated if necessary.

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2.2.6 Create File Structures (Task 6)

In this task, the system administrator implements the conventions that you agreed on in Task 5, "Develop Approach". If you omit or postpone this task, you will pay for it in confusion or disruption later.

2.2.6.1 Create Project Directory (Box 6a)

The system administrator creates the directory that will hold the base and alternative case project files.

2.2.6.2 Create Project-Specific Data Directory (Box 6b)

The system administrator creates the directory that will hold any project-specific versions of TAAM static data files that may be required in the study. See Section 3.3, "Static and Project-Specific Data" for details.

2.2.7 Build First-Level Input Files (Task 7)

2.2.7.1 Create Preliminary Timetable (Box 7a)

Because of the large amount of information contained within it, the timetable (or flight schedule) in the form of the TAAM ACF file will almost certainly evolve throughout the course of the project. It is not important at this early stage to have a complete or bug-free ACF file. In fact, study requirements that surface later may require fundamental changes in the form assumptions regarding the ACF file. At this time, use the same sources for traffic schedules, such as System Analysis Recording (SAR), the Official Airline Guide (OAG), or the Enhanced Traffic Management System (ETMS) that you plan to use for the study to create a rough ACF file with approximately the correct number and type of flights. The objective is to create an ACF which will allow for the iterative model refinement process to begin as quickly as possible. Because of delays in obtaining, processing, or adding route information to the source data, this process can be a bottleneck for the TAAM study.

2.2.7.2 Create Weather and Winds Files (Box 7b)

Assumptions regarding airport weather and en route winds tend to be static and change infrequently in the course of the project. Therefore you can invest the time to build these files at this time at a low risk of needing to make major modifications later.

2.2.7.3 Create Sectors (Box 7c)

Assumptions regarding airspace sectors tend to be static and change infrequently in the course of the project. Therefore you can invest the time to build airspace polygon files at this time with a low risk of needing to make major modifications later.

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2.2.7.4 Create Background Maps (Box 7d)

Assumptions regarding the appearance of geography or ATC background maps tend to be static and change infrequently in the course of the project. Therefore you can invest the time to build these files at this time with a low risk of needing to make major modifications later.

2.2.7.5 Determine Initial Simulation Parameters and Options (Box 7e)

Based upon the project scope, assumptions, and metric requirements discussed in the project kickoff meeting you should be able to decide which features (options) in TAAM should be enabled and what modifications should be made to default project parameter values. These options and parameter values will almost certainly change in the course of the project so you should not invest a large amount of time attempting to precisely specify them at this time, but do what you can with the knowledge available.

2.2.7.6 Obtain or Digitize Preliminary Airport Layouts (Box 7f)

A detailed airport layout is not necessary for every study. If you do need an airport layout, contact The Preston Group, Embry-Riddle Aeronautical University, and other members of the TAAM users community and request any required airport layouts. No matter how well digitized, airport layouts from a third party may need extensive customization to be consistent with your particular modeling needs. If you cannot obtain adequate airport layouts then digitize the layouts from architectural drawings. Even if airport layouts are readily available, this process can still be very time consuming and is often a bottleneck for a TAAM study.

2.2.8 Build Second-Level Input Files (Task 8)

2.2.8.1 Create Preliminary Waypoints, Airports and Routes Files (Box 8a)

Do not begin this process until you have created a preliminary ACF file because the waypoints, airports, and routes (if used) required by the study are not totally known until the ACF file exists.

2.2.8.2 Create Preliminary Airport Usage, SIDs, and STARs Files (Box 8b)

Do not begin this process until you have obtained the required airport layouts. These files reference the runways named in the airport layouts and cannot be created until the layout exists. Building Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARs), and specifying airport usage is usually a time consuming process and this step is often a bottleneck for a TAAM study.

2.2.9 Build Preliminary Base Case Project File (Task 9)

Because you now have preliminary versions of all the data needed to attempt a simulation run, you can create a preliminary project file with pointers to those preliminary data files. Name this file something like "basecase."

2.2.10 Run Early Test (Task 10)

Execute the preliminary Base Case project. You will almost certainly find problems, some of which prevent the simulation from running at all. Fix the high level problems (file permissions, environment settings, pointers, incorrect data structure, etc.) so that the simulation can run. Correct any obvious problems so that the simulation will run in at least a rough approximation of reality, but don't try to tune the simulation yet.

2.2.11 Build Alternative Case Project File (Task 11)

Make a copy of the preliminary project file and name it something like "alternative."

2.2.12 Confirm Modeling Feasibility (Task 12)

Take the study design statement you developed in Task 5, "Develop Approach", and build simulations that address each one of the study elements described in that statement. Your objective here is to ensure that TAAM is capable of representing every aspect of the real world system that is critical for your study. Don't rush this task, because it can save you from many difficulties later. However, this can be a very challenging task, and certainly has the potential to be a project bottleneck.

2.2.12.1 Base Case Experimenation (Box 12a)

Begin with the "basecase" project that you built in Task 9 and got to execute in Task 10. Add all the features you will need to address the elements in the study design statement. You aren't trying to build a finished product; you are trying to answer the question "Is this study possible?" Now is the time to refer to Section 4, "How to Build and Verify the TAAM Simulation" and Section 5, "How to Refine the TAAM Simulation" in this document and all your TAAM reference material to look for options, examples and suggestions.

2.2.12.2 Alternative Case Experimenation (Box 12b)

Perform the same exploration on the "alternative" project as you did for the "basecase" above.

2.2.13 Reassess the Study (Task 13)

Reassess assumptions, scope, tools choice, timelines, metrics, etc. based on any difficulties discovered in Task 12, "Confirm Modeling Feasibility". If necessary, discuss and negotiate appropriate changes with the client.

2.2.14 First Development Cycle (Task 14)

The majority of time required to conduct a TAAM study falls within this process that develops the preliminary models into reliable and accurate final models. Since there is usually very little difference between base case models and the various alternative cases, they should not be developed separately. The base and alternative case models should grow together in cycles of increasing fidelity. Often, the only development of the alternative that must happen is to ensure that, as the base case model evolves, the required functionality of the alternative cases (developed during the experimentation in Task 12, "Confirm Model Feasibility") continues to work. This process consists of five separate activities that should be done repeatedly to improve the simulation with each iteration. It is unwise to expect that one or two model refinement efforts will result in an accurate model. The following steps may be repeated (to some degree) dozens of time in the course of a study. (Refer to the TAAM Reference Manuals or TAAM Practical Guide for specific guidance on individual features.)

- **Augment and Correct Data**. Based on model performance and requirements set for the study, fill any gaps in your data from the most reliable sources possible. These data may include standard routes through the airspace, ATC refinements to published SIDs and STARs, additional flights not contained in previous timetables, specification of more detailed ground facilities at an airport (long term parking positions, hangars, etc.), separation standards, procedure specifications, and restrictions.

- **Update Model**. Based on information collected from navigational charts, ATC, or other study team members, refine and update the model. You may need to update the model even in the absence of new data in order to tune parameter values to achieve the desired effect in the simulation.

- **Generate Output**. In order to assess the overall performance of the simulation, execute the model. Make sure that the model is set to generate the output needed to draw conclusions about its performance (turn on messaging and/or output generation).

- **Verify**. Verify the model input and parameters to ensure that the models accurately represent the modeling team's understanding of the real world system. Note that "verification" is not the same as "validation", which is performed in conjunction with an external validation team and evaluates the suitability of the model for its intended

use. Use the Interactive Data Input System (IDIS) log, TAAM log, and message file to identify terminated or ignored flights and use error message text or "show logic" functionality to identify and correct problems.

- **Archiving**. Save project files and data files very frequently and archive them at the end of every day. Setting up an automatic archiving routine to do this for you is a worthwhile effort.

2.2.15 Prepare for Preliminary Validation (Task 15)

Model validation is a formal process where you meet with the client for a thorough review of the model's input, output, assumptions, and run-time behavior. If the outcome of this review is that the client accepts the model as suitable for use, then you are ready to use the model for running the agreed-upon experiments. Validate the base case and all the alternative cases in a TAAM simulation study before using the results to infer conclusions.

Count on holding at least two validation meetings, a preliminary one at this stage of the project and a later one for refinement and final acceptance. The preliminary meeting can be extremely valuable for uncovering gaps and inconsistencies in simulation assumptions.

When you prepare for a validation meeting, identify views in the model that may be of particular interest to your client and devise techniques for presenting these succinctly. Review each scenario and correct any obvious errors. The aspects of the model you emphasize for validation will vary from project to project. Typical candidates for model validation (discussed in detail in Section 4.4, "Verification and Validation") are:

- Flight schedules

- Ground movements

- Flight tracks

- Procedures

- Restrictions

2.2.16 Hold Preliminary Validation Meeting (Task 16)

Set up the validation meetings to contain the following elements:

- Status briefing

- Working session

- De-brief

In the status briefing, discuss modeling assumptions, data sources, preliminary results, and the status of verification efforts. In the working session, the client can view the simulation running and pose questions. That session is your opportunity to call attention to the key features in the model and highlight any areas of concern. In the de-brief, discuss any remaining problems in the model and agree on how to achieve a satisfactory correction. Allow enough time for an introduction, viewing of the simulation, and a closing discussion (several days may be needed for large studies).

2.2.17 Second Development Cycle (Task 17)

The activities in this task are essentially the same as in Task 14, "Execute First Development Cycle' but they are now informed by what you have learned in the preliminary validation meeting. You may have discovered new data during the meeting and may need to change simulation parameters. This is a cyclic task like Task 14.

2.2.18 Prepare for Final Validation (Task 18)

The activities in this task are essentially the same as for the preliminary validation meeting in Task 15, "Prepare for Preliminary Validation", but applying to the updated simulation.

2.2.19 Hold Final Validation Meeting (Task 19)

See the notes on holding the preliminary validation meeting in Task 16, "Hold Preliminary Validation Meeting" above. The model is considered to be "valid" if it is a sufficiently accurate representation of the corresponding real world problem from the perspective of the intended uses of the model. It may be a good idea to remind the participating domain experts that "valid" for a simulation does not mean the same as "indistinguishable from the real world system". Explicitly ask if the validation team considers the model "valid" in the simulation sense of the word. If not, identify a list of problems to resolve and make and make arrangements to allow the validation team to confirm that every problem on the list has been resolved. Fixing the last 10% of a TAAM simulation can take much more than 10% of project time and getting an external validation team to give final approval may be difficult (even if remaining unresolved items do not affect the study metrics). As a result, this task and Task 20 can combine to be a costly bottleneck late in the TAAM study.

2.2.20 Conclude Simulation Development (Task 20)

Do not perform any significant data collection or model development activities after the final validation. Address and document the resolution of any problems that were identified during the final validation. Also document the internal verification of any simulation model

changes. Prepare the project files and data directories for the final production runs to generate model output.

2.2.21 Make Production Runs (Task 21)

Use a batch file to run final version of the base and alternative cases. A batch file is a good idea at this point because it allows you to audit the contents of each batch file to confirm what inputs you are entering. Refer to Section 6.1, "Preparations and Checks" for details on preparing for the production runs.

2.2.22 Calculate Metrics (Task 22)

Use tools, as necessary, to calculate study metrics based upon TAAM model output. These tools may be the TAAM reporter, spreadsheet applications, or customized post processors.

2.2.23 Document Project (Task 23)

Complete the final report describing the entire study and its results.. You may deliver this product in the form of a paper, an electronic document, a briefing, or all three. Refer to Section 7, "Presenting the Results of a TAAM Study" for sample formats.

2.2.24 Conclude the Project (Task 24)

2.2.24.1 Delivery (Box 24a)

Present the final results of the study to the client in the form of a briefing, a written report, or both according to your agreement made earlier. Allow the client some time to consider the results and provide feedback. In some cases a supplemental deliverable may be required to clarify some results.

2.2.24.2 Final Archiving (Box 24b)

Move project data files out of working TAAM data directories and compress and archive them in an appropriate place. Ideally you will archive this data in multiple locations including a CD-ROM which should also contain project briefings and deliverables presented to the client.

Section 3

Working with TAAM Input Data

This section applies to three tasks shown in Figure 2-2[*], "Task Flow for a TAAM Study" where you collect and manage data. The first place is the combination of Tasks 7 and 8 (Build First and Second-Level Input Files) where you build the initial project for feasibility testing. The other two places where this section applies are the "Collect Data" steps in Tasks 14 and 17 (Execute First and Second Development Cycles).

3.1 Categories of TAAM Data

TAAM studies cover three aviation domains:

- Airport:
  Ground movement of aircraft at the airport, including movement to and from the gate, taxiway, and runway.

- Terminal Area:
  Aircraft approaching a runway on arrival or departing from a runway on departure

- En route:
  Aircraft operating between terminal areas.

Although it can sometimes be convenient to look at aviation system problems in terms of just one of these domains, in practice the performance of each of these subsystems can be strongly affected by the others. You will find that most TAAM studies use elements from all three domains, though not all at the same level of detail.

What all of these domains have in common is that they all must be combined with a flight schedule describing the air/ground traffic that will move in that domain.

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[*] Figure 2-2, "Task Flow for a TAAM Study" is a three-page foldout at the end of this document.

3.1.1 Airport Level of Detail

Because the amount of data required to represent an airport in TAAM can be very large, TAAM offers the capability to represent airports at three levels of detail called (from coarsest to finest):

- Pointwise

- Runway-only

- Detailed

An airport defined at the coarsest level of detail is called a *pointwise* airport. Pointwise airports are simple sources or sinks for simulated aircraft. A departure flight from a pointwise airport proceeds in a straight line to the first waypoint in the flight plan without following the realistic departure maneuvers specified for an airport as observed in actual operations. Similarly, an arrival flight to a pointwise airport proceeds in a straight line from the last waypoint in the flight plan without arrival maneuvers. The pointwise airport is useful when your simulation covers a large geographical area and the maneuvers around that airport do not have an effect on the results described in your study objective.

A *runway-only* airport has the coordinates of each of its runways defined, but no taxiways or other ground features. In a runways-only airport, each runway becomes a source and sink for simulated aircraft. When you have defined runways for an airport, the aircraft departing from or landing at that airport follows specified departure and arrival maneuvers either implemented by the modeler or generated by TAAM. The aircraft also is subject to runway and wake turbulence separation standards, runway dependencies and runway separation rules.

A *detailed* airport has a ground layout that includes the coordinates of each runway as well as taxiways, gate parking positions, long-term parking positions, hangars, and aprons. The amount of data required to represent an airport in TAAM can be very large. The ground layout may also include locations of de-icing pads, if these are applicable to your study. The detailed airport layout allows your TAAM model to have an explicit representation of the surface contributions to flight delay: pushback, taxi, crossing taxiway intersections, entering and exiting the runway. A detailed airport layout may be relevant to your study even when your study objective doesn't explicitly mention ground operations because ground operations can constrain the arrival and departure rates for each runway, particularly at airports with more than one runway.

The level of detail for each airport represented in your TAAM study is an important trade-off decision. A detailed airport layout can be costly both in the time it takes the analyst to build it and in TAAM simulation performance. However, the pointwise or runway-only airport cannot be used to model the complete gate-to-gate air traffic complexity. There is no

single right approach; you must refer to your TAAM study objective to determine how much detail to use in representing each airport.

3.2 Overview of TAAM Data Requirements

To account for all the different attributes of an airspace system, a TAAM simulation can use over 30 different types of input file (see the TAAM Plus Reference Manual for details). Although you probably won't have to populate all these file types for any single study, you will still need to collect and interpret a large amount of data. Some of the challenges of data collection for TAAM are:

- **Data sources**: It is unlikely that any single reference or person will be able to supply all the data you need. You will probably have to consult many documents and interview several subject-matter experts.

- **Data mapping**: There is generally no one-to-one relationship between TAAM input files and data sources. Some input files will require information from several different documents, and some sources (particularly interviews with air traffic control staff) may be used in several TAAM input files.

- **Data interpretation**: You may discover parameters in the TAAM input files that don't appear to correspond to any values in your source information. By the same token, your sources may give you values for parameters whose description doesn't appear to correspond to anything in the TAAM input. Be alert for differences in terminology: a "trombone" is also called an "extended downwind leg" and a "dogleg" is called a "vector".

Data collection is an iterative process because it is difficult to predict at the beginning of a study exactly which data you will need. You can make an initial assumption about which data your simulation requires, but you will need to revisit that assumption as your study progresses.

3.2.1 Basic Data

This section discusses some of the data file types that will appear in most or all TAAM simulations. Default versions of all files listed in this section are available with the TAAM installation with the exception of the traffic and routes files which must be customized for each project.

3.2.1.1 Traffic

You will often need to incorporate information from several different sources to define the traffic input for your simulation. You want to give particular attention to the traffic file because it plays the key role of defining the simulation event schedule. Section 3.2.2 discusses some details of developing the traffic file.

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3.2.1.2 Waypoints

Waypoints are fundamental components for many model elements in TAAM. Waypoints are used to define flight paths in en route and terminal areas (SIDs, STARs). Some of the waypoints you use in a study represent published fixes, navigation aids, and airports in an existing or projected airspace configuration. You may also need to define additional waypoints to represent details needed by TAAM for constructing an aircraft's trajectory in the terminal area (SIDs and STARs). If the waypoint file is large you will notice that TAAM's performance at simulation start-up is correspondingly degraded. Therefore it may be worth the effort to tailor a waypoint file for a project containing only the waypoints you need to model in that project.

3.2.1.3 Routes

Flight plans in the TAAM traffic file may include routes in addition to or in place of a series of waypoints. The TAAM route file allows you to name specific routes between certain airports or waypoints. When that route name appears in the traffic file, TAAM expands the route into the series of waypoints defined for that route.

3.2.1.4 Aircraft Performance

TAAM uses aircraft performance data to model the aircraft movement in the air and on the ground. The performance characteristics defined in this file dictate an aircraft's climb/descent profile at certain altitude bands, optimal cruising altitude, airborne turn radius, landing speed, and the landing requirements at the airport.

You may want to calibrate aircraft performance for a particular study in the following circumstances:

- Where your simulation has a requirement for operations that are airline- or airport-specific. Airlines may require pilots to follow specific maneuvers at specific airports, which would not otherwise happen in the simulation using the standard aircraft performance for the airframe type. In this case, you can define a distinct aircraft type (for example, B737_SWA for Southwest Airlines) that generates the aircraft behavior you want to simulate.

- Your study represents take offs and landings for an airport at a high altitude or high temperature. In order to adjust the aircraft ground acceleration and deceleration, get a visual estimate from the local tower controllers of the points on the ground where the aircraft of typical types or sizes would rotate or turn off the runway. Experiment with different values of ground acceleration and deceleration until you observe take off and landing rolls corresponding to the controller's estimates.

- The air traffic in your study does not conform to the US global restriction of Indicated Air Speed (IAS) not to exceed 250 kt below 10,000 ft. The default performance files supplied with TAAM impose this restriction.

- The commercial air traffic represented in your study uses different Mach numbers from the manufacturer-specified Mach numbers supplied with the default performance files.

- You want to impose generic ATC/Air Traffic Management (ATM) through the performance data. For instance, you can "build in" the restriction that all aircraft on descent will fly at less than 210 kt IAS below 5,000 ft. An alternative way to impose this condition is to define speed restrictions in the STARs.

3.2.1.5 Magnetic Bearings

The magnetic bearings file contains correction values to convert between latitude-longitude and compass readings. Because the earth's magnetic field changes, you should update this file at least once a year.

3.2.2 Air Traffic

The file containing the scheduled air traffic for a TAAM simulation is called by several names, including "Traffic File", "Flight Plan Data", or "Flight Schedules". These all refer to the <filename>.ACF file as described in the TAAM Reference Manual, which also defines the various permissible formats for this file. Appendix B, "Developing Flight Schedules" discusses some techniques for developing the flight plan data.

3.2.2.1 Flight Plan Data Checking

However you develop your flight plan data, you will want to use IDIS for automated error checking.

Check the following elements using the IDIS Log *List Errors* button:

- Any messages containing text "Flight removed" or "Flight ignored". (Use the *Find* key to locate these flight records)

    – The underlying reason may be that the aircraft type is not defined in either the Aircraft Performance Characteristics file or in the Aircraft Types (aliases) file.

    – Another reason may be a missing waypoint in a complete route. If the flight plan refers to a complete route (with @R in the timetable) and one or more of the waypoints in that route is not defined, TAAM will discard the route and consequently discard any flight using that route. Look for signs of this problem such as a "Route ignored" line earlier in the IDIS Log or messages about undefined waypoints or airports.

- Any flight plans that contain direct references to waypoints

    – IDIS may just generate a warning; skip those waypoints but retain the flight.

- Any routes defined more than once

    – If a complete route is defined more than once, IDIS will remove the second and all subsequent references to this route, that is, all affected flights. If you find an instance of this case, run a complete check on the Routes file.

- Any corrupted or incomplete records. These can occur when you forget to run the IDIS View/Modify function on the timetable, and hence it still contains question-mark characters for ETD (estimated time of departure) or ETA (estimated time of arrival) or cruising altitude.

3.2.2.2 Altitude Checking

If the cruising altitude was not specified in the underlying traffic data file, IDIS will assign an altitude automatically. Therefore you should check the preferred altitudes in the Aircraft Performance Characteristics file at the beginning of each data block where the operational ceiling is defined.

Another source of altitude errors is using truncated flight plans (where inbound aircraft start at waypoints closer to destination airport rather than the departure airport). If you import a timetable, the cruising levels or transitional levels in the original flight plan may prove to be too high for aircraft that are initiated airborne at a waypoint. The consequences of the high altitudes is that these aircraft will not be able to descend in time, will be too fast and will disrupt the landing sequence. So if you are using a truncated flight profile, put the start point before the Top of Descent or change the cruise altitude to a lower altitude corresponding to the aircraft's descent profile.

3.2.3 Data for an Airport Study

An airport simulation model is composed of airport objects, procedures, and environmental factors (such as weather).

3.2.3.1 Airport Objects

The airport objects typically include runways, gates and aprons, taxiways, hangars, parking positions, and deicing pads. You need to have an airport layout containing the information to define these objects. TAAM allows the user to specify constraints for how each object can be used in the simulation. TAAM collects statistics on the activity of each object. Other airport elements such as buildings, obstacles, and taxiway borders may also be included in the layout for visual reference.

3.2.3.2 Airport Procedures

Airport ground procedures are often complex and have significant impacts on airport delays. Consequently, it is important to use great care when implementing these procedures by specifying the characteristics of taxiways, gates/aprons, and other objects as well as usage rules and parameters in the usage file.

- **Gate and Apron Specifications**
  - Airlines allowed to use each gate
  - Aircraft types allowed to use each gate
  - Market segment (for example, "domestic" or "international") allowed to use each gate
  - The minimum aircraft service time between flights at each gate
  - How long an aircraft is allowed to stay at each gate before being towed long-term parking position or hangar

- **Hangar, Parking Position, and Deicing Pad Specifications**
  - Characteristics similar to the ones for gates – you can constrain their use to certain airlines, aircraft types, or flight categories.

- **Taxiway Specifications**
  - Whether the direction of flow on each taxiway segment is fixed or changes dynamically with respect to on runway configuration or some other condition
  - Whether certain taxiways are used for "land and hold short" operations
  - Maximum speed allowed on the taxiways
  - Limits on how many aircraft are allowed to taxi out simultaneously
  - Limits to the queue length for each departure runway
  - Other preferences or restrictions on the use of each taxiway

- **Runway Specifications**
  - Intervals between pairs of runway operations, that is, the distance or time between arrival and arrival, arrival and departure, and departure and departure
  - Dependencies between two or more runways for arrivals or departures
  - Any standard practices for balancing traffic on the runways
  - Special requirements for VFR or commuter flights

- Definitions of all runway configurations relevant to your study; for example, east and west flow (which runways are open for arrivals, departures, both, or closed)

- Under what conditions the airport will make a transition between configurations

Other modeled airport procedures include the strategy for placing arriving aircraft in the arrival sequence, the maximum length of departure queues for each runway, and how the aircraft separation minima change depending on the current weather situation.

3.2.3.3 Airport Weather

The airport weather conditions include wind velocity, visibility, cloudbase, temperature, and precipitation. You can change the airport temperature to adjust aircraft performance without editing the aircraft characteristics file, but be sure to record the reasons behind such a change in the weather files.

3.2.4 Data for a Terminal Area Study

This section describes the types of data required for a TAAM analysis of terminal airspace. The elements of a terminal environment model are the terminal layout and the procedures for arrivals and departures.

3.2.4.1 Terminal Layout

Use the following elements as parts of the terminal area layout to build a terminal area simulation:

- **ATC Background Maps**. Background maps are used in air traffic control displays as a visual aid for the controllers. Background maps display known landmarks and obstructions such as rivers, towers, mountains, and buildings, in addition to symbols representing navigational aids, runways, departure corridors, and final approach areas. Overlaying such a map in the TAAM simulation display helps the model developers and the operational team to comprehend and verify simulation details.

- **Sector boundaries (if applicable)**. Sector boundaries are used to define three-dimensional airspace. Sector boundaries allow the user to segregate one area from others visually, set parameters specific to the area (such as aircraft separation minima and conflict resolution strategies), and collect statistics on the area.

- **Map with state boundary or coastal outline (if desired)**. Geographical references such as political boundaries and coastal outlines, overlaid in the simulation display, helps the model developer and the operational team to comprehend and verify simulation details.

3.2.4.2 Arrival Procedures

- **Standard Arrival Routes (STARs)**

  - STARs define the arrival path to the runway. A STAR consists of a series of waypoints (published and user-defined) with optional altitude and speed restrictions at each waypoint. A particular STAR's usage may be restricted to certain types of aircraft.

    You can build a STAR based on the published material such as the Jeppesen charts or airport procedures. However, these charts usually do not contain the final directions to the runway threshold, because common practice (in the USA) is for the aircraft to be given vectors by the controller. To get input for this part of the STAR, consult with the operational team (local controllers) or study the recordings of radar track reports. In instances where more than one arrival route is defined between an arrival fix and the airport, the user may define multiple TAAM STARs and rules to enforce guidelines of conditions for aircraft to use each STAR.

    Although it is important that the TAAM STAR follows the actual route the aircraft flies, the definition of the TAAM STAR needs to be consistent with TAAM's internal requirements. You may need to insert small deviations in the STAR definition to facilitate sequencing.

- **Airborne holding (holding fixes and holding altitude/pattern)**

  - Holding is one of the mechanisms TAAM uses to absorb airborne delay. Define holding fixes and associated data with reference to the published data. Note that whether the holding actually occurs at the intended holding fix in the simulation or not depends on certain sequencing parameters as well as the number of aircraft arriving at the airport.

- **Trombone approaches, vectoring patterns**

  - Tromboning (extending the down wind) is another of the delay absorbing mechanisms. Obtain the distance of the extension from the operational team. TAAM has a very limited vectoring mechanism. The only way to implement vectoring without writing complicated rules is to use doglegs. But because doglegs in TAAM are available only in restricted conditions, they are usually not practical.

3.2.4.3 Departure Procedures

- **Standard Instrument Departures (SIDs)**

  – SIDs define the departure maneuver from the runway to the departure fix. A SID consists of a series of turn instructions and restrictions on speed and altitude. SID usage may be restricted to certain types of aircraft.

  – You can build a SID based on the published material such as Jeppesen charts or airport procedures. Verify SIDs by looking at radar track reports and by consulting the operational team (local controllers). There may be more than one departure route defined for a departure fix/airport pair. Cover this case by building multiple SIDs and specifying SID selection guidelines with rules.

  – In building a SID, take account of nearby airports with special procedures and departure separation requirements (Miles-in-Trail, wake turbulence, radar separation).

3.2.5 Data for an En Route Study

This section describes the types of data required for a TAAM analysis of en route airspace.

3.2.5.1 En Route Data

To model the en route airspace, the following data are required:

- En route airspace sector map (including magnetic variation)
- Map with state boundary or coastal outline if desired
- Special Use Airspace (restricted areas)
- Winds aloft

3.2.5.2 En Route Procedures

To model the en route airspace of interest in TAAM, the following procedural information is required:

- Radar separation minima
- Any in-trail separation requirements for Terminal/Center transition
- Any non-radar (procedural) sectors and associated separation minima
- In-trail separation requirements for particular fixes or routes
- RNAV routes, in particular any offsets from the nominal routes

- Reduced Vertical Separation Minima (RVSM) or other reduced separation mode

- Flight level allocation rules (such as Flight Level Allocation Scheme [FLAS] being proposed in Europe) if different from standard semi-circular rule

- Initial and final flight levels if aircraft are introduced into the simulation at waypoints rather than airports

- Altitude/speed restrictions in sector boundary crossing

Points to check:

- Decide whether you need to model conflict detection/resolution in all the sectors. These functions degrade TAAM's performance markedly, so you want to dispense with them whenever possible. Determine whether conflict detection/resolution can be disabled for "uncontrolled" airspace (that is, not covered by any sector in TAAM), as well as for some ATC sectors.

- If controller workload is a desired output, make sure that the relevant statistics get collected. An example of a type of controller workload in TAAM is the coordination that occurs when aircraft change sectors. In this case, define the coordination between each pair of sectors as an output.

- Set the sector capacity, the maximum instantaneous number of aircraft in the sector, for each sector. Define the actions TAAM should take if the capacity is reached or exceeded. Define techniques to mitigate excess traffic when sectors are at capacity: gate holds, rerouting, or a combination of techniques.

- Check aircraft performance characteristics to ensure that TAAM uses the correct Mach numbers for cruising.

- Check the altitude/speed restrictions defined for sector boundary crossing. If these are not consistent with the normal flight behavior, you may need to implement them using STARs.

3.3 Static and Project-Specific Data

Some of the data contained in the TAAM input files apply to a particular simulation. These data include the timetable, airport data, waypoint and route data, wind data, and sector layout and are called *project-specific* files (see Chapter 1 in the TAAM Reference Manual). On the other hand, certain TAAM input files describe aviation system features that hold many different simulations and can be shared across projects. These files (known as the *static* files) include aircraft performance characteristics, required wake turbulence spacing between different aircraft weight classes, and definitions of the market segments. At the time of writing this document, there were eighteen possible types of static file.

Each type of static data has a default file in the applicable directory. These files are loaded in the simulation at the start up time. However, you sometimes need to modify static files to achieve consistency between the actual operation and the simulation model during model calibration. For example, you may want to modify the aircraft performance file to simulate aircraft behavior specific to the airport or airline being studied (see Section 3.2.1.4 Aircraft Performance above).

In order to avoid conflict with other projects that share the static data, when you modify a static file, give that file a different name and specify it by name in the project file. This will not affect your other projects or other users' projects (and their modified data will not affect you.) Use project-specific files whenever you are working with two or more TAAM projects that need to refer to different versions of the aircraft performance characteristics file or any other static file.

3.4 Data Fidelity

It is important to decide on the level of fidelity required for the study. For example, if all you have is a city pair for route information, TAAM may still be able to allocate the correct SID or STAR to the aircraft and fly it along a Great Circle track between the two destinations. This fidelity may be enough for most airport ground studies and some terminal area studies where the traffic flow in and out of the area matters, but how aircraft reached the terminal area does not. In practice, however, airports large enough to be the subject of simulation studies tend to have arrival or departure fixes that have a complex geographic relationship to the connecting airport. In these cases, the route information should include the arrival or departure fix. But this stripped-down route definition is insufficient for en route airspace simulation where the exact flight route is important.

If you use the TAAM defaults in the absence of detailed information about runway allocation rules, SIDs and STARs, the model may not be satisfactory for a terminal airspace study. However, for airports far enough away from the terminal area being studied, default SIDs and STARs and a pointwise airport (see Section 3.1.1) may supply sufficient detail.

Note that when you are studying a hub (terminal area) where one or two carriers are dominant, instead of using generic TAAM aircraft performance data, you should adjust the data to reflect the way these carriers fly their aircraft. In those cases, the climb rates, descent rates and cruising speeds may be different from the generic definition for each aircraft type.

If you are adding detail for the sake of additional fidelity, be sure that it "pays its freight". Entering extra data is time consuming and can slow down simulation execution.

3.5 Proceed With Caution

Every TAAM study presents unique challenges and there is no single or simple formula that will always serve to describe how to transform your data into a working TAAM simulation. It may mitigate the inevitable frustration if you keep in mind that:

- **TAAM is complex**. A TAAM simulation is defined by dozens of parameter settings, rules, and file pointers. There are many opportunities for an error to invalidate your simulation. Perhaps you have defined a rule incorrectly and the aircraft are not flying where you expect to see them. Once you have corrected the rule, the simulation may still not show the correct behavior because you haven't activated that rule. When you notice that the rule isn't active and turn it on, you may discover that the rule never executes because another rule always takes priority. An incorrect file name can cause one of your input files to be ignored. Although these kinds of problems are usually easy to fix, they can be extremely difficult to identify.

- **Your assumptions may not match TAAM's assumptions**. The entities defined in TAAM do not necessarily possess all the attributes, behavior, and influence on the aviation system of their operational counterparts. Be on the alert for assumptions you may make based on your understanding of how the real world system behaves. For example, you might assume that TAAM, in representing aviation systems under positive control, would enforce aircraft separation standards at all times, however under some circumstances TAAM may not enforce aircraft separation on the final approach segment.

- **TAAM has limitations**. For all its complexity, TAAM still does not have sufficient entities, variables, and rule options to model all the relevant aspects of an aviation system. In order to build your model, you may be forced to be inventive to obtain the desired results. Some of this can be quite harmless, for example, defining two fixes with the same co-ordinates to represent a single fix which is a holding point for two altitude levels, a concept that doesn't otherwise exist in TAAM. But you should take extra pains to validate the effects of any ideas that use TAAM constructs in unusual ways. You would do better to omit a capability altogether rather than to risk having a dubious implementation contaminate your entire simulation.

Section 4

How to Build, Verify, and Validate the TAAM Simulation

This section applies to every task shown in Figure 2-2[*], "Task Flow for a TAAM Study" where you are integrating the individual data sets discussed in Section 3 into a complete aviation system model. These places are Task 10, "Run Early Test" and Task 12, "Confirm Modeling Feasibility" where you are defining the basic outline of the model. This section also applies to Tasks 14 and 17 (Execute Development Cycles) where you iterate to improve the detail and fidelity of your model. For a more advanced discussion of these topics, see Section 5.

4.1 Airport Surface

4.1.1 Airport Layout

The physical characteristics of airports and airspace can have profound impacts on the simulation study and its conclusions. Because these characteristics are so complex, it is easy to overlook flaws in the physical description that can lead to inaccurate study conclusions. Therefore you will want to verify all the items on this checklist:

- Runway lengths

- Distances between runways

- Distances between runways and first tier taxiways

- Number of gates, gate locations, distance between gates

- Location of stand-off positions and long term parking positions

- Runway touchdown distances

- Location and type of runway entrances and exits

- Runway entrance and exit points precisely at the center of the runway

- Taxi path segments are connected at both ends

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[*] Figure 2-2, "Task Flow for a TAAM Study" is a three-page foldout at the end of this document.

4.1.2 Ground Movements

When you are verifying ground movement, examine each runway configuration and taxi flow separately. This process does not lend itself well to quantitative analysis, so visual inspection is the usual approach. One of the important things to look for is any discontinuity in taxiways, or between a runway and a taxiway. If you see a ground track or runway exit that appears to be a natural path for an aircraft to follow where you never observe any ground traffic, check the detailed definition of the taxiways to make sure that all the ground paths are actually connected. If you are checking gate usage, particularly if the traffic file contains linked flights, consult the TAAM Practical Guide under Terminal Airspace Study: Flight Number and Aircraft Registration Number for guidance.

See Section 4.4.2 for a discussion of ground movements validation.

4.2 Terminal Airspace

Getting the aircraft onto and off the runway is one of the most complex problems of air traffic control. The paragraphs in this section are a compilation of useful facts and suggestions to have at hand when you are developing a terminal airspace model in TAAM. Refer to the TAAM Reference Manual, the TAAM Practical Guide, and your materials from TAAM training for definitions and more information.

Verify the following elements in any terminal area study:

- Location of arrival fixes
- Location of departure fixes
- Location of runways
- Location of airspace boundaries
- Location and status of any Special Use Airspace or other restricted airspace
- Definition of STARs
- Definition of SIDs

4.2.1 Airspace Sectors

All airspace (both terminal and en route) is divided into sectors that delineate the volume of airspace that is the responsibility of a single air traffic control position. You build and modify the sectors using TAAM's Gtool. Refer to the TAAM Practical Guide "Building Sectors" under "Terminal Airspace Study" for detailed recommendations on building sectors. Refer to Section 3.3, Static and Project-Specific for warnings about setting the parameter files for a sector file that is used in more than one TAAM project.

4.2.2 Departures

4.2.2.1 Building SIDs

Refer to the TAAM Reference Manual and the TAAM Practical Guide for the elements to use in building SIDs. If you find that the simulated aircraft do not exhibit the behavior you expected on SIDs, here are some SID features to consider:

- **Turns**

  TAAM will slavishly obey "turn left" and "turn right" directions for an aircraft even if it means flying a loop. Unless you are certain of the turn direction, use the "Auto" turn to allow TAAM to select an efficient turn.

- **Crossing radials**

  If you have put in a clause that takes effect when an aircraft crosses a radial "To" or "From" a Very High Frequency Omnidirectional Range (VOR), that clause will activate whenever the aircraft crosses the extended "To" or "From" line (great circle arc) that passes through the VOR, regardless of the distance between the aircraft and the VOR.

- **Restrictions**

  Because the aircraft flying the SID will activate only one restriction of each type ("Do not climb above", "Do not exceed IAS",…) at a time, sometimes you will have to define a restriction using two clauses.

  Restrictions (altitudes, speeds) defined in a SID will be imposed on the aircraft only until it reaches the SID reference point (the waypoint in the SID name). If you want a SID restriction imposed beyond the reference point, consider extending the definition of the SID to include a further reference point.

4.2.2.2 Selecting SIDs

Although TAAM contains default SID selection logic, you will usually want to write rules controlling which SIDs get selected for different types of departures. When the airport you're studying has multiple runways, sometimes there is an obvious geographical split: "traffic departing west will normally use Runway 01L, and traffic heading east, Runway 0lR".

You can also introduce more subtle variations, including dynamic traffic balancing, preferred origin/destination cities or preferred departure/arrival fixes for each runway. When you are working with runway objects in TAAM rules, remember the double-clause reference, for example,

> *If(aircraft.departing is True*
>
> *AND runway.name is "26L"*
>
> *AND runway.lineup_q_length > 10*
>
> *AND ...)*

Note that you need to include a reference to an aircraft in the first clause, and that you need to state the runway name before any reference to that runway's parameters.

4.2.2.3 Separation from Arrivals

The separation that TAAM imposes between an arrival and a departure on the same runway is called the Runway Capture Distance. In many cases, the minimum runway capture distance is about 1 nm. That is, a departing aircraft can begin to line-up when the arriving aircraft is no closer than 1 nm from its touchdown point (not the same as the runway threshold), but you should verify this assumption with tower controllers.

4.2.2.4 Runway Separation

TAAM applies VFR runway separation on same runway according to the settings in the file *data/dat/sep_stand.data.* The International Civil Aviation Organization (ICAO) standard separation is that the previous departure must be at least 6,000 feet distant and airborne (for other-than-small aircraft). For simulations in the US, that standard may be too tight. A TAAM calibration for several major US airports showed that, if the radar separation waiver is applied under VFR, a runway separation of 9,000-11,000 feet produces more realistic departure flow rates and aircraft spacing. For small aircraft, 5,000-6,000 feet may be a more realistic setting than the ICAO default which states that the departing flight must be at least 2,000 feet distant and airborne.

In IFR, TAAM uses the full runway length for runway separation and the above values do not apply.

4.2.2.5 Airborne Separation

When you are modeling a busy terminal area with multiple large airports, put the "Airborne Conflict Checks for Departures" setting to "yes" and put the "Conflict Detection" setting to "enabled" to prevent instant conflicts on departure. Refer to the TAAM Practical Guide under Terminal Airspace Study: Airborne Conflict Check for Departures for details.

4.2.3 Sequencing

TAAM contains two "threshold parameters" to simulate sequencing of aircraft for final approach: the Landing Queue Threshold and the Sequencing Action Threshold. These are discussed in the TAAM Practical Guide.

Set the Landing Queue Threshold parameter large enough that the flight selects its runway and STAR while it is about 45-60 minutes or 250-400 NM away from the airport. The aircraft cannot select its STAR until the aircraft crosses this threshold, so be sure that the circle whose radius is the Landing Queue Threshold contains all the STAR entry points. Also make sure that the circle whose radius is the Sequencing Action Threshold contains any designated holding points (see "Holding" below.) Bear in mind that if you define the Sequencing Action Threshold only in terms of time, then by the time the slow aircraft in your simulation are sequenced, they may already be too close to the airport. To avoid that problem, use the "Greater of Time/Distance" option. For more discussion of sequencing in TAAM, see Section 5.2.3, "Problems with Sequencing".

4.2.4 Delay

4.2.4.1 Holding

One of the signs of an effective terminal area model is that aircraft do not hold at "temporary holding fixes". TAAM creates these fixes when it has run out of other options for delaying the aircraft. Holding at these "temporary fixes" usually does not correspond to any normal air traffic procedures. To prevent holding at a temporary fix, make sure that you build enough slots into holding stacks and define STARs so that sequenced aircraft on the STAR still have named waypoints and user-defined holding points ahead of them.

4.2.4.2 Trombones

Trombones (also known as "extended down-wind" or "stretched path") are such a flexible delay-absorption method that you should define them for any final approach unless airspace limitations preclude their use. To ensure effective use of the trombones, design the STARs to that runway so that the intercept angle between the base leg and final approach is no more than 45 degrees.

4.2.5 Separation on Arrival

4.2.5.1 Final Approach to a Single Runway

TAAM takes several factors into account when calculating separation on Final Approach. (See discussion of radar separation below.) The resulting separation will be the largest of all applicable. For example, if the radar separation standard is 3.0 nm, that separation applies for two turboprops landing one behind the other, rather than the wake turbulence separation

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which is smaller. However if the leading aircraft is a B747, then a wake turbulence separation of 5.0 nm or 6.0 nm applies instead.

4.2.5.2 Radar Separation

The parameter "Radar separation on Final" in TAAM refers to separation at the runway threshold, not at middle or outer marker. Therefore, if you want to set separation in the middle of the Final Approach to be 3.0 nm, you accomplish that by setting "Radar separation on Final" to about 2.7 nm, because the separation at the runway threshold is smaller than at the middle marker.

TAAM calculates the radar separation on Final Approach by locating the mid-point of the final STAR segment and taking the radar separation for the sub-sector containing that point. TAAM applies that radar separation at the runway threshold.

There are several implications of this calculation:

- Because different runways may have different approach sectors or subsectors, you should check the separation in each one of them. Remember that although the required separation for most major airports is 3.0 nm or even 2.5 nm, the default TAAM separation is always 5.0 nm.

- If you have just one large "generic" terminal airspace sector surrounding the airport, its "airspace" separation (used for conflict detection) may be larger than you want for "Radar separation on Final". In that case, you can create either a smaller subsector of the same sector or an independent small sector around the runway(s) and set a smaller separation there.

- If the middle point of the final approach segment is not covered by any sector, then the default radar separation will apply, so check the *data/dat/sep_stand.data* file used in your study. Also check the value of the *Default Seq Interval for Same Runway* parameter on the *Sequencing* panel.

- In air traffic control practice, even if the nominal radar separation is, say, 3.0 nm, in good visibility it may be waived resulting in substantially smaller separation for smaller aircraft – possibly 2.0 nm. If you can confirm that this waiver does hold in the facility you are modeling, then apply the smaller separation.

- Radar separation on Final in TAAM applies only to separation on the same runway. See the next section for the case of separation between aircraft landing on different runways.

4.2.5.3 Traffic Landing on Different Runways

Check the runway relationships carefully. Remember that:

- In versions earlier than TAAM Plus 1.1.2, TAAM does *not* apply wake turbulence separation on different runways, even if they are dependent. In these cases use a "Staggered Distance" parameter or airport usage rules to impose wake turbulence separation between aircraft on different runways.

- If the two runways do not physically cross, or if the intersection is so far away from their thresholds that landing traffic may never even reach it, TAAM nevertheless calculates the imaginary intersection moment in order to calculate the sequencing gap. For such cases, set the "Crossing RWYs Clearance Gap" parameter to a small value.

- Use the "Crossing RWYs Clearance Gap" parameter for the simpler cases of crossing runways. This parameter defines how far the following aircraft will be from its touchdown when the leading aircraft on the crossing runway passes through the intersection. In more complicated cases or for multiple crossing runways (airports such as KORD or KBOS), you will need to use airport usage rules.

- Use the "Staggered Distance for Parallel RWYs" parameter in the simpler cases of dependent parallel runways. This parameter defines the diagonal (not along the runway) separation between the two aircraft landing on the parallel runways. For more complicated scenarios (where you have more than two parallel runways, or need to set up additional wake turbulence separation) use Airport Dep/Arr Sequencing Rules to define behavior.

4.3 En Route Airspace

4.3.1 Restrictions

The variety of ways airspace restrictions are defined and enforced defeats any consistent procedure for incorporating them into a simulation model. Airspace restrictions usually take one of four forms:

- Altitude limits

- Speed limits

- MIT behind the leading aircraft

- Avoiding restricted airspaces (such as Special Use Airspace)

4.3.1.1 Altitude Restrictions

Altitude restrictions usually take one of three forms:

- Departure restriction

    A departure restriction requires the aircraft to be less than or equal to a certain altitude until a waypoint or boundary is crossed. After that the aircraft can ascend to cruising altitude. For example,

    ```
    All flights departing Buffalo and passing over the
    boundary between sectors ZOB33 and ZOB74 have a
    departure restriction of 27,000 ft at that boundary.
    ```

- Arrival restriction

    An arrival restriction requires that the aircraft descends so that it is at or below a certain altitude when the waypoint or boundary is crossed. For example,

    ```
    Flights from Washington area airports to Detroit have
    an arrival restriction of 29,000 ft over the ZID-ZOB
    boundary.
    ```

    ```
    All jets arriving passing over the fix Newlo and
    arriving in Detroit have an arrival restriction of
    24,000 ft at Newlo.
    ```

- Cruising altitude restriction

    A cruising altitude restriction requires that the cruising altitude of the aircraft be less than or equal to a certain altitude. For example,

    ```
    Flights from Indianapolis to Detroit are capped at
    (cannot fly higher than) 23,000 ft.
    ```

To impose a cruising altitude restriction for selected flights, specify the cruising altitude in each flight plan.

Do not attempt to specify arrival or departure altitude restrictions by editing flight plans or by writing airspace rules. The only reliable technique for imposing arrival and departure altitude restrictions is to extend SIDs and STARs beyond their published limits. Extend SIDs or STARs by including waypoints that would otherwise be in the flight plan. Implement a 3,000 ft altitude restriction in a SID by adding a "Do not climb above 3000 ft until…" statement at the end of the SID definition. Specify altitude restrictions in STARs by entering either a pair of altitudes or "at or above" or "at or below" restrictions. For example, typing " – 3000" in the altitude column for a point on the STAR indicates that any altitude at or below 3,000 ft is acceptable. Similarly, typing "3000 – " in the altitude column for a point on the STAR indicates that any altitude at or above 3,000 ft is acceptable. If you want to associate

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an altitude restriction with a boundary, determine the point where the flight crosses that boundary and implement the restriction at that point.

See the TAAM Reference Manual for more details on using IDIS for including restrictions into SIDs and STARs. A restriction described in a SID or STAR will apply to every flight that selects that SID or STAR. Note that extending a STAR to incorporate an arrival altitude restriction may have implications for setting the Sequencing Action Threshold. For additional discussion of sequencing in TAAM, see Section 5.2.3, "Problems with Sequencing".

4.3.1.2 Speed Restrictions

You set speed restrictions by building airspace rules or incorporating speed limits into SIDs and STARs. You can also edit the aircraft performance file to adjust the cruising speed for an aircraft type.

4.3.1.3 MIT Restrictions

You can enforce MIT restrictions by setting the MIT restriction for individual fixes in the waypoints file. Make sure that you also check "Intrail Separation" in the simulation options. Normally, the MIT settings for the waypoint should be "Any Direction" and "Same Altitude", so that all aircraft crossing the waypoint at the same altitude will be separated, but aircraft that are already separated by altitude are not. This is not always the correct case, so confirm these settings during validation. Note that when TAAM determines whether two aircraft are at the same altitude, it refers to the aircraft assigned cruise altitude, *not* the current altitude.

Aircraft are often delayed on the ground awaiting departure due to MIT restrictions at the departure fix. Consult the TAAM Reference Manual on departure sequencing in the Airport Usage file to ensure this feature works properly for your study.

4.3.1.4 Dynamic Airspace Use Restrictions

Representing dynamic restrictions on Special Use Airspace and other restricted airspace calls for different approaches. If you can assume that a piece of airspace is closed to traffic throughout the entire study period, then route flights around that airspace by ensuring that their flight plans do not penetrate that airspace. You can include restricted airspace areas in a TAAM simulation as if they were airspace sectors and use Gtool to give the restricted areas a distinctive display color. An IDIS display of the restricted areas and predetermined routes facilitates inspecting the airspace. If you identify any routes used in this study that penetrate any restricted area, you can modify those routes to avoid restricted areas entirely.

If the restricted airspace areas will be open as well as closed to traffic during the time of the simulation study, you can achieve dynamic route selection by using airport usage rules

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and airspace rules. The Arrival/Departure Sequencing rules in the airport usage panel allow you to write rules that change the routes used by departures. These rules are effective when an airspace restriction is based on static characteristics of the aircraft and time of day. Note that the Arrival/Departure Sequencing rules evaluate the decision to re-route only at the point at which the aircraft departs. If the restricted area becomes open to traffic after departure, the aircraft will not be able to use it unless directed to do so by an airspace rule. Airspace rules offer the opportunity to base the choice of route on aspects of the airspace itself, and on characteristics of the aircraft at the time of flying en route.

4.4 Verification and Validation

The two "V and V" words are often used interchangeably, but in simulation studies they are used to describe two different processes. You *verify* that a simulation has been correctly built and is using appropriate data input. You *validate* whether a simulation produces results that are sufficiently accurate for a particular application. For a very thorough discussion of verification and validation, see *Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide*, 1996, Office of the Director of Defense Modeling and Simulation Office (DMSO).

4.4.1 Validate Flight Schedules

Although the flight schedule is an input to a TAAM simulation, it is an output of what can be an intricate data preparation. So the process of verifying that the flight schedule is suitable TAAM input becomes a form of validation also.

Even when you use actual flight schedules, you may find significant discrepancies between the number and type of flights in the simulation and what you expected. The causes of these discrepancies may be missing data, or inappropriate choice of a sampling day.

Produce hourly arrival and departure counts at all the airports of interest, and break down the types of operations at those airports. Report the percentage of air carrier, air taxi, General Aviation (GA), cargo, and military operations at each airport of interest. Review these numbers to ensure that a specific kind of operation is not being under-represented, and that the total and distribution of flights throughout the day are consistent with the client's expectations.

4.4.2 Validate Ground Movements

Since it is difficult to produce graphics or numeric results that describe ground operations, observation of the simulation (also called "face validation") is the best validation approach. This validation technique is consistent with the visual control that is used by tower. Give the client or operational specialist some time to view the entire airport operation to see the general level of activity, large-scale taxi flows, and overall gate utilization. Then call special attention to the following areas:

- Gate usage – Tower controllers can quickly identify incorrect airline-to-gate, or aircraft-to-gate assignments by observing specific apron areas while the simulation is running.

- Runway entrances – One technique for improving an airport's departure capacity and delay statistics is to allow intersection departures from points other than the runway end. If this technique is in use at the airport being modeled, confirm that the TAAM model displays the same behavior.

- Runway exits – An airport's capacity is a function of runway occupancy time, which is in turn a function of runway exit usage. Examine runway exit usage giving special attention to aircraft types using different exits.

- Number of aircraft in stand-off positions – Tower controllers have a good sense about the number of aircraft waiting for gates during busy periods. The numbers indicated by TAAM should be compared to their intuitive beliefs. This process often reveals hidden problems with gate allocation or gate occupancy schemes.

- Towing operations – Examine towing operations to ensure they travel to and from the correct areas along appropriate routes.

- Taxi flows – Airports usually operate with parallel taxiways being used separately for arrivals and departures. Also, airports sometimes forbid aircraft to taxi through one apron area to get to another. Confirm these behaviors in the TAAM simulation.

- Individual taxiway usage – Some taxiways are meant to be used only by specific aircraft types. Confirm that none of the forbidden types use these taxiways in the TAAM simulation.

4.4.3 Validate Flight Tracks

Flight tracks can be very useful for calibration and validation. For example, you can convert Automated Radar Terminal System (ARTS) or SAR tracks, or ETMS TZ messages, into TAAM format. Then, with "Conflict Checking" option and "Predicted Path" display option enabled and in 2D mode, observe flights without any "redisplay" or "zoom". In this mode, TAAM leaves the position marks of ghost (conflict probe) aircraft on the screen. Then you can take a screen printout or JPEG screen shot to use in SID/STAR development and further TAAM base case calibration. Note that when you select a "redisplay" or "zoom", all previous tracks will disappear.

4.4.4 Validate Procedures

TAAM studies often involve characterizing the impact of procedural changes in the airspace (for example, changing conflict resolution strategies) or at airports (for example, implementing dual arrival streams). In such a case, your validation presentation should

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include a detailed description of the procedure, how it works, and under what circumstances it is used. Identify and present sample cases to show how the procedure works under various conditions. Construct scenarios to demonstrate the implementation of the procedure so the client can see it in action.

4.4.5 Validate Restrictions

The major technique for validating airspace restrictions is once again "face validation", that is, having a subject matter expert observe the simulation while it is executing. Create sample cases, which are instances of the restriction being enforced. A sample case consists of a short document describing the restriction combined with a time, a location, and an aircraft identifier to show the restriction having its effect in the simulation. Let the client or operational analyst confirm that known altitude and speed restrictions are satisfied in the simulation.

Be aware that there might be cases where a restriction is not documented and can be identified only by knowledgeable sponsors viewing the simulation one sector at a time. The differences between TAAM terminology and ATC terminology can be significant here. Because air traffic controllers may not refer to a requirement that certain aircraft fly at specific altitudes over an arrival fix as a "restriction", this requirement may not be uncovered until the validation effort.

Section 5

How to Refine the TAAM Simulation

This section covers advanced versions of the topics covered in Section 4. The material in this section applies to all the tasks shown in Figure 2-2*, "Task Flow for a TAAM Study" where you are building or refining the parts of an aviation system model. These tasks are Task 10, "Run Early Test", Task 12, "Confirm Modeling Feasibility", and the "Execute Development Cycles" Tasks 14 and 17.

5.1 Verifying Simulation Operation

Many problems you will encounter with simulations are the result of data that are insufficient for the scale of the project at hand. When TAAM encounters a data problem in the course of flight processing, it will usually ignore that flight. Therefore, it is impossible to see a data problem from the simulation graphics. Take care to review the various log files, and ensure that all the flights that ought to be in the simulation actually get simulated.

5.1.1 IDIS Diagnostic Files

When a project is loaded into IDIS, a log file is generated that contains detailed reports on any data errors or warnings (`./IDIS_LOG`). Unfortunately, IDIS generates a warning message any time a flight's estimated time enroute is greater or less than the difference between the scheduled time of arrival and the scheduled time of departure. Because these messages usually don't give any information that will lead to run-time problems and there can be a great many of them, they impede your search for the critical information To find the important warning messages, use a text editor or a UNIX-grep to search for the strings "ignored", "not found", and "may be rejected".

It is critical to review this file and make the necessary additions and changes to the airport, waypoint, route, and aircraft characteristics files *before* you save the timetable in IDIS. If you save the timetable by mistake, IDIS will delete any flights that use unknown elements. Also, if you are simulating a single airport, it is common to specify the time only at that airport, and use a question mark for the other end of the flight. After you have saved the timetable in IDIS, however, that question mark is replaced by a time, and subsequent changes may or may not preserve the time at the important end of the flight.

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* Figure 2-2, "Task Flow for a TAAM Study" is a three-page foldout at the end of this document.

For an additional margin of safety, it is a good idea to keep a backup copy of your original or latest version of the ACF file so that if you do save the timetable in IDIS by mistake, all you have to do to recover is make a file copy.

For the first simulation of a new area, the "check" functions in IDIS are useful to identify errors in the airport, waypoint, and route files. In practice, however, you seldom generate new files from scratch. If you copy a file from a previously-verified project, and you use IDIS to add new airports (waypoints, routes), checking will not yield any new information.

5.1.2 TAAM Diagnostic Files

It is imperative that you use TAAM error diagnostics regularly and pay full attention to them, especially at every stage of model development. Errors left uncorrected in the Base Case will propagate down to study alternatives. Check the diagnostic files frequently and thoroughly.

5.1.2.1 TAAM Log (`./TAAM_LOG`)

Look in the TAAM log for messages about any data files omitted or corrupted, flights not loaded due to data inconsistencies, incorrect airport layouts, and other important TAAM system messages. A very good diagnostic for ground simulations is the presence of the string "gridlock" in the TAAM log. Sometimes problems in the ACFT_CHARACT file can cause the simulation to terminate without writing any messages to the TAAM log. The IDIS_LOG does catch these problems, so be sure that you have checked this file with IDIS.

5.1.2.2 Messages (`reports/username/project.msg`)

Watch for aircraft terminated before departure or after arrival. The strings "terminated" and "Terminated" indicate that TAAM is removing flights from the simulation, which is a sure sign of problems.

If you are new to Unix systems, it is a good practice to select *To Screen and File* as the standard option for TAAM messages. You don't need to enable all messages all the time, instead select those really needed for your particular study. If you are proficient in Unix, you can speed up the simulation significantly by selecting *To File* only. File I/O is faster than screen I/O, so in that case there is no need to be frugal with message enabling. As the simulation is running, look at the tail of the message file in a command window, or "grep" for significant events.

Messages contain good additional information that is not always available from other diagnostics (for example, runway selection; sequencing delays; sector boundary crossing), and also, certain TAAM system messages of importance to the user will be sent to this message window and to the project-specific file. Remember that you won't get the value out of the message file unless you remember to turn messages on in the first place.

5.1.2.3 Reports `(reports/username/project.rep)`

This file is most easily accessed via the Report Presentation Facility (RPF), which can be used while the simulation is running. Hourly operations counts are the simplest way to identify a problem with operations. Once you have identified a problem area, it is a good idea to look at the smaller time divisions, such as ten or fifteen minutes, to get the details. Generally, controllers can tell you a benchmark number of operations to expect. If throughput is too low, separations are too high.

After the operations counts are verified, look at the delay distribution for arrivals and departures separately. Departure and arrival delay peaks don't have to be the same but they often have a similar order of magnitude. If one delay type is much higher than the other, a further investigation may be worth while. If the arrival delays are extraordinarily high, arrival separations are too large. If departure delays are extraordinarily high, arrival separations are too small. (TAAM favors arrivals whenever possible.)

It also makes sense to look at delays by source:

- High taxi delays may be caused by inefficient ground layout and may skew the overall delay reports;

- High gate delays may prompt you to check gate turnaround times and also gate allocation rules, which may identify a gate that is not being used, due to some combination of rules and gate properties;

- For arrivals, high sequencing delays may indicate a separation problem, or a flow control problem, whereas high taxi delays may indicate, say, runway crossing bottlenecks.

5.1.2.4 Flight Summary File `(reports/username/project.sum)`

Check the top of this file for aircraft with unusually high delays. Also, check for obvious patterns of the delayed flights: Are they all arrivals or all departures? Are they all at the same airport (if you're simulating more than one)? Do they all use the same runway? These patterns suggest demand/capacity mismatches that undercut simulation quality. Note that this file is not written until the user has pressed "quit", so it is not available while the simulation is running.

"Average Delay Per Flight" from this file is also useful. Several industry sources mention two thresholds: average delays of 6 minutes per aircraft (for the day) indicate that the airport is nearing reasonably full capacity (but is still capable of operating normally). The average delay of 10 minutes per aircraft is the threshold beyond which the airport becomes saturated and airline schedules break down. Remember that the delays that TAAM reports may not correspond to actual delays. Another useful measure of excessive delay is when delays are so large that two successive flight banks merge together.

If the average delay TAAM produced is high compared to these, the reasons can be:

- Flow control settings (Target Arrival Flow Rate) are too pessimistic.

  This can be verified by checking the En route Delay component of the Total System Delay report. Increasing the Target Arrival Flow Rate may lead to somewhat increased airborne holding on approach to the airport but the delay will be reduced.

- Demand is artificially high.

  For example, in a recent airport study, a full VFR schedule was used with low-visibility weather conditions and reduced runway capacity. This produced very high average delays. In reality, airlines would proactively cancel flights to reduce demand and this reduces delays. When the higher number of cancellations were factored into the TAAM simulation, delays went down substantially.

- Setup is incorrect.

  If the TAAM simulation does not achieve the capacity that the real airport can achieve, check that you have applied all the suggestions in the TAAM Practical Guide for maximizing airport capacity.

5.1.2.5 Show Logic Diagnostics

Even if the traffic looks reasonable on the screen, it is still useful to run some additional checks, especially for departure and arrival separation (sequencing). The "Show Logic" panel is the only way to assess the effectiveness of rules. The messages in this panel are extremely detailed, and numbing in their repetitiveness, but you must look at it a few times per simulation.

For departures, find an aircraft that has not yet reached the lineup position (if taxiing is enabled) or whose ETD has not yet come (if taxiing is disabled), open its "Show Logic" panel, select "Lineup" from the diagnostics menu and observe the diagnostics being written in the text window. It needs to be examined to see what kind of wake turbulence, radar, runway or other (rule-induced) separation TAAM used. There are sequencing diagnostics as well, but they are not very useful for departures.

For arrivals, find an aircraft that has not yet reached the "Sequencing Action Threshold" (that is, has not yet sequenced), open its "Show Logic" panel, select "Sequencing" from the diagnostics menu and observe the diagnostics. Check the radar, wake turbulence, and any other separation applied by TAAM for sequencing.

For taxiing aircraft, find an aircraft that is just about to push back from the gate, and select "Taxiing" from the diagnostics menu. If the correct rules are executing, their names will appear in the window.

These checks should be performed on a number of departing and arriving aircraft of different categories, on different runways, to get a full picture whether departure and arrival separation in this TAAM project is correct.

It is strongly recommended that you review the "Maximizing Your Airport Capacity" section in the TAAM Practical Guide when all the above elements are in place.

5.2 Handling Common Problems

5.2.1 Flights Using Wrong Sectors

Pay special attention to defining which sectors are considered "inner" by TAAM. When an aircraft is inside the 2D projection (the ground contours) of several sectors, TAAM needs to find the innermost sector for it – and the sector with smallest contour is not necessarily the innermost. Consider the two sectors, A and B, having different upper and lower boundaries, and a point inside the contour of sector B representing an aircraft location.
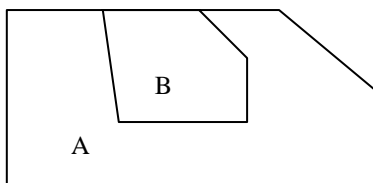
This is an example top (plan) view of two sectors. Four relationships between the sectors are possible – the drawings below represent the side views of sectors A and B for each relationship:
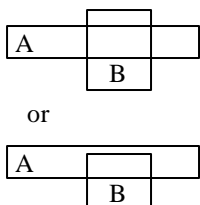
For each of the two cases where B's lower boundary is below A's, TAAM will consider the aircraft to be in sector B. To put the aircraft in sector A instead, split sector B vertically into two or three subsectors. (Actually, the first case usually only occurs as a simulation technique to cause a particular airspace rule to execute.)

For each of the two cases where A's lower boundary is below B's, TAAM will consider the aircraft to be in sector A. To put the aircraft in sector B instead, split A into a subsector wrapped around B and a subsector laterally contiguous with B. Then adjust the floors and ceilings of the subsectors until the desired behavior is obtained.

The Sector Movements report is the place to validate airspace. If there are major discrepancies in sector usage between TAAM and your validation standard:

- Examine the definition of the SIDs and/or STARs, especially their vertical profiles.

- Check the order in which the sectors are recognized by TAAM. It may be that the movements reports are written into the wrong sector.

- Check the altitude use in flight plans (at individual waypoints).

- Confirm the definition of airspace rules for correct altitude changes.

- Confirm that runway use percentages are correctly set in terminal airspace sectors: any imbalance there will affect sector movement statistics.

- Check for errors in SID and STAR selection, which in turn may lead you to check departure and arrival fix selection rules.

5.2.2 Rule-Writing Practices

Most TAAM users are familiar with the experience of creating a rule of elegant construction and seemingly impeccable logic, that nevertheless is ignored by the simulation. Unfortunately, there is no easy way to check rules other than by executing them (and looking at the "Show Logic" diagnostics). There are several common sources of misbehaving rules: logic errors; failure to identify all the objects involved in the rule; bad timing; incorrect object names or units; and incorrect rule priority.

5.2.2.1 Logic Errors

Logic errors can be either genuine mistakes or failure to comply with TAAM's restricted set of logical conventions. Bear in mind that that the "or" disjunction is not very useful. Clauses joined by an "or" are combined in a non-standard way, and are not recommended. (Refer to the TAAM Reference Manual for specifics.)

Groups are a good way to remove almost all need for "or" disjunctions. A clause such as

IF aircraft.curr_taxiway is "twA1" OR aircraft.curr_taxiway is "twA2"

can always be replaced with a group, say "taxiwayA", containing all the segments of interest. When more complex logical constructions are desired, other disjunctions can be made by using two rules with the same "then" clause. Finally, you can accomplish the effect of "or" in the "then" clause, not formally possible in any case, through the use of sets of entities with or without percentages.

DeMorgan's Rule is another common logical trap. The correct opposite of, say,

IF(aircraft.name is "UAL" OR aircraft.name is "AAL*")*

is

IF(aircraft.name is_not "UAL" AND aircraft.name is_not "AAL*")*

Note that the clause connector has changed from *OR* to *AND*.

5.2.2.2 Specifying Objects

A rule begins with objects: aircraft, runways, SIDs, taxiways, etc. Each object has properties to which the "if" clauses refer, and properties that can be changed by the "then" clause. Every rule must contain a reference to the aircraft, or it will never execute. Other objects are optional, depending on the function of the rule. Therefore, the best way to begin writing a rule is to identify the objects:

IF (aircraft.arriving is TRUE AND runway.name is "27L" …) THEN ...

After all the objects are collected, then specify properties. This method, while somewhat harder to read, has the advantage that it catches another common problem immediately: it is not permitted to specify two objects of the same type in an "if" clause. This rule will not work (no matter how much we wish it did) because it specifies two runways:

IF (aircraft.arriving is TRUE AND runway.name is "26R" AND runway.lineup_queue_length > 15 AND runway.name is "27L" AND runway.lineup_queue_length < 5) THEN …

5.2.2.3 Object Names and Units

It is easy to enter an incorrect object names. Be sure to check how TAAM expects to see the object name typed. SID and STAR names are the file names, without the extension. Objects in an airport layout do not have their class attached: aprons or runways are referred to in the rules as *DO use apron {A, B},* not *DO use apron {Apron A, Apron B}.*

Simple typographical errors are always a possibility. This is especially true for taxiway names such as *twy_cl125* – these are often confused with, say, *twy_cl1125*.

Units are expressed differently in different parts of TAAM. In departure/arrival sequencing rules, the only acceptable units are *min* or *nm*; always specify one or the other. Do not specify units for speed and altitude rules. Speeds are always in knots. Altitudes are always in FL, even when the aircraft is on a STAR or SID.

5.2.2.4 Bad Timing

Unless a rule is executed at the correct time, it will have no effect. Consider the order in which TAAM assigns ATC resources to aircraft. For arrivals, the runway is chosen before the STAR, so a STAR selection rule that forces the selection of a STAR for another runway will be too late to execute. (The same thing happens for SID selection, but selecting the SID after the runway is intuitive, so it doesn't cause as much trouble.)

For taxiing aircraft, TAAM chooses the runway, and then the taxi path before the aircraft pushes back. You can force a change in taxi path at a trap point where you do a recheck , but take note that when the aircraft reaches the trap point, it is too late to do the recheck Therefore, the following rule will not work:

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IF(aircraft.curr_taxiway is "twy_cl123") then recheck_taxipath_at {twy_cl123};

Here is the correct way to phrase the rule:

IF(aircraft.departing is TRUE) then recheck_taxipath_at {twy_cl123};

Attempts to use the rules to make the sequencing interval for arrivals dependent on the length of the departure queue are often unsuccessful because of the time lapse between the moment when the aircraft is put in the sequence and when it actually lands. The situation with departures may change dramatically during those 20-30 minutes. If there is no leading indicator of the situation that will obtain as the aircraft lands, the rules may have to be phrased in terms of time of day.

5.2.2.5 Rule Priority

Another reason that a rule does not execute properly is that it may be overruled by another rule with higher priority. TAAM reads rules from bottom to top, and executes everything with an "if" statement that evaluates to TRUE. If there are active rules with the same "if" above the suspect rule, they may contradict it.

Finally, a rule which does not have its activation box checked has no priority at all, and will never be executed.

5.2.3 Problems with Sequencing

Sequencing is perhaps the most complex part of TAAM. It is also the hardest part to get correct. The basic mechanism of sequencing is to slow aircraft or speed them to achieve a desired separation over the runway threshold. The reason this is difficult is that all other ATC actions, conflict resolution, flow management, rerouting, etc., use the same mechanisms to achieve their separate goals. As a result, the various actions can contradict one another. The best practice in this case is to separate the various functions as much as possible. When problems are seen, check the interactions among target flow rates, in-trail separation, and conflict resolution.

Two types of sequencing problems are common; excessive spacing between flights and insufficient spacing between flights.

5.2.3.1 Excessive Spacing

The problem affects every new simulation project. The first step for resolving the problem is to check that the radar separation in the final approach sector has in fact been changed from the default of 5.0 nm. As mentioned above, the "Show Logic" panel is useful here. After that:

- Use an aircraft performance data file such as the file available on the TPG website (or a file similar to it) with the following characteristics: Aircraft speed profiles on descent should be smooth; enough envelope should be provided (minimum-normal-maximum IAS); deceleration should be sufficient to slow down to the next slower speed on descent.

- Use speed restrictions on STARs sparingly, and wherever possible, use the "not above" option ("-210" means "not above 210 kt IAS"). These restrictions should be realistic, that is, coordinated with aircraft performance on descent.

- Enable trombone approaches for arrival runways whenever possible. Trombone approaches are TAAM's preferred method of absorbing delay for separation. Many controllers are unfamiliar with the term "tromboning"; the term "extended downwind leg" is also used. If the controllers say they do not use tromboning, try the other term, and check the radar data.

- Designate a holding pattern, with low enough "bottom of the stack", for every identified holding fix. Ideally, each approach track will have its own holding pattern(s). This is TAAM's last resort for absorbing delay. If a modeled holding fix does not exist, TAAM will make one, which will usually be unacceptable to the validating controllers.

- Put the "Sequencing Action Threshold" outside the holding fixes. If the threshold is too close to the airport, it may not leave enough room to form a good sequence and use speed control.

- Define flow control or traffic flow metering (using in-trail separation) to help TAAM cope with the incoming flow in the terminal area. However, these can interfere with sequencing actions, if your arrival fixes and holding fixes are the same. Test problematic airports by toggling in-trail separation on and off in the simulation.

- Design the paths of sequenced aircraft so that they are procedurally separated and not subject to conflict resolution actions. These actions can disrupt the sequence. Applying conflict avoidance action to non-sequenced aircraft, such as departures, should not affect the sequence.

- Design the length of the final approach segment (the last segment of each STAR) to be at least 6 to 10 nm. A shorter final segment may not allow the aircraft to attain properly reduced speed on final approach.

- Experiment with both "Flow ETA" and "Sequenced ETA" to discover which is the more suitable strategy for the problem you are modeling. There isn't any general rule to decide which of the two sequencing strategies in TAAM is better: it depends on the traffic scenario.

5.2.3.2 Insufficient Spacing

The second type of problem with sequencing occurs later in the simulation project. Its characteristic symptom is that two aircraft will land very close together, or even on top of one another. This loss of separation is a consequence of an inconsistency between the calculated time to fly the STAR, and the time the aircraft actually takes. The cause is generally awkward STAR design. Check the STARs for the close pairs of aircraft. If one STAR in particular shows up in a preponderance of the cases, examine it for features that cause errors in TAAM's flight time estimator. These features may be one of the following:

- The STAR has a turn of more than 90 degrees;

- The STAR merges with other STARs at the turn from their downwind to base legs;

- The two STARs lie very close to one another, but they are different enough that TAAM does not see them as flying a common path.

Trial and error may be the best way to correct the offending feature.

5.3 Improving Simulation Efficiency

A simulation that runs in a short time, say less than an hour, is easier to refine and more accommodating of changes than a multi-hour or overnight simulation. When deadlines are tight, running time can limit the amount of testing that can be done. (That is definitely not the best practice.) Therefore, an efficient simulation is likely to be better validated and more robust than an inefficient one.

Running time is dependent on the hardware available, but assuming that your computer platform is fixed, huge improvements can still be made in simulation efficiency by careful design. You can improve simulation efficiency by using some general principles:

- Turn off simulation features that will not affect your answer.

- Do not include modeled resources you do not need.

- Break your study into independent pieces.

- Simplify your timetable.

- Use element properties instead of rules, where possible.

- Set unneeded parameters to values that speed execution.

5.3.1 Use Simulation Features Only When Necessary

TAAM is designed to simulate many features of the air traffic management system. If you don't need a feature, then turn it off. This improves the efficiency of the simulation, as well as making it easier to analyze problems. The case for turning a particular feature on or off depends on the study; listed below are general guidelines.

- **Wind**. Wind is usually specified in the study plan. If you are studying it, you need it.

- **Aircraft performance randomization**. You can deactivate randomization if you are studying en route airspace, or the airport surface. It is frequently necessary for studies of terminal departure routes.

- **Conflict checking and automatic conflict resolution**. Deactivate conflict checking and resolution if you are studying procedurally-separated airspace, such as a terminal. Pure ground models do not need these features. Note that conflict checking and resolution are activated by default in a new project.

- **In-trail separation**. It's a delicate decision whether to use in-trail separation or not. It interferes with sequencing in many cases (up to TAAM Plus v.1.1.1), and sometimes must be deactivated to get good sequencing to the arrival runways. However, it is a prerequisite for automatic flow limitation.

- **Sequencing**. Sequencing is almost always necessary. It is the part of TAAM that distinguishes it most from other simulators, so if you don't need it, you're probably not using TAAM in the first place. An en route or oceanic study that includes no airports will not need sequencing. Sequencing is activated by default.

- **ATC sectors**. You don't need to define ATC sectors for a ground study, unless you are using them to trigger rules. An airspace study that considers only user metrics (delay, miles flown) will not need sectors as long as the differences among sectors are not important (that is, they all have the same separation standard). If this is true for your study you can deactivate ATC sectors in favor of the separation standards outside controlled airspace (in data/conf/sep_stand.data). This feature is activated by default.

- **Graphics**. You don't need graphics for final production runs, but they are important the rest of the time. Graphics are activated by default.

- **Report generation**. Report generation accounts for a significant part of the load that TAAM puts on the Central Processing Unit (CPU), but if you deactivate it, you lose the raw material for debugging. You can duplicate many of the capabilities of the report presentation from the message file, but the programming required may take more time than it is worth. Report generation is activated by default.

- **Sector capacity**. Sector capacity limits are more useful to trigger rules than as a direct part of the study. "Sector Capacity" is deactivated by default and should be left deactivated unless you need it.

- **Gate usage**. The default setting for gate usage is "Auto Gate Assign". Unless you are simulating the airport surface, set it to "No Gate Usage". This is critical – it can affect your output results if you are using randomization.

- **Messages**. The messages are your best tool (after graphics) for debugging, so turn on all relevant ones and send them to a file. It costs time, but it is worth it. The default setting turns off all messages except conflicts, and sends them only to the screen.

5.3.2 Reduce Modeled Resources

Most beginners create their first simulation by combining files created by others, especially the airport and waypoint files that come with TAAM or the immense reference files from Embry-Riddle Aeronautical University (ERAU). This is a good way to make sure that all necessary parts of the simulation are in place and no flights are ignored, but it costs a great deal in simulation startup and run time. Once you have created the timetable, you can throw out unused airports, waypoints, sectors, and so on leads for a big improvement in end-to-end time. The "shrink project" utility from ERAU is useful for this.

Exclude SIDs and STARs that will not be used. Because every flight has to run through the whole list to make its choice, a shorter list makes a more efficient simulation. The history file tells which SIDs and STARs were actually chosen by your traffic. In particular, if your simulation uses a single runway configuration, omit any STARs that do not go to the arrival runway, and SIDs that do not come from the departure runway.

5.3.3 Break Simulations into Independent Pieces

When the simulation volume is a large terminal airspace, you may be tempted to put the major airport and all its satellites into a single simulation. Unless you are using conflict detection or sector capacity, or the airports share MIT restrictions, a single simulation is not necessary. TAAM will give identical results in several small projects. Sequencing and flow management to different airports are independent. TAAM does not enforce departure separation between departures from different airports (unless they use a common departure fix where miles-in-trail restrictions are in effect). Therefore, most simulation questions do not require a large, single simulation. Even if sector counts are the desired output metric, the instantaneous counts may be added from the different simulations.

5.3.4 Simplify the Timetable

Flight trajectories in TAAM should contain as few waypoints as possible. For an important gain in simulation efficiency, eliminate all waypoints between the airport and the intended departure fix and between the arrival fix and the airport. (If your source for route data is ETMS, you will see many of these.) These waypoints complicate the selection of SIDs and STARs, but do not contribute to the simulation.

En route, there is no value to waypoints that lie along a great circle, unless you need them to impose an altitude or MIT restriction, or to trigger a rule needs. If the aircraft does not turn, climb, or descend, omit the waypoint.

5.3.5 Minimize Use of Rules

Rules are the most powerful means of controlling the simulation, but they are also the most expensive in computation time. Any time that desired behavior can be obtained without rules, the simulation will run faster. There are two ways to minimize rules. The first is by defining object properties, the second is by taking advantage of the "implicit rules", that is, the TAAM default behavior. It is easy for the analyst to overlook potential applications of object properties, since rules do the job without repetitious clicking on dozens of gates and taxiways.

Reading the flow of decisions in the "Show Logic" window gives clues to TAAM's default choices. An example for a ground model is gate assignment. TAAM's default behavior is to choose a gate that is near the top of the list of gates in the usage file. Therefore you should sort the list according to how the airport functions. Putting this list in order is a significant amount of work, but it pays off in run time. The list has to be in some order, at least conceptually, so you might as well have it in a way that leads TAAM to make the correct choices without the need for rules.

Another example of using properties to eliminate rules, this time for an airspace model, is SID/STAR selection. TAAM's default behavior is to choose the first valid SID or STAR that it finds in the project file. Therefore, if a particular SID is to be used at night, it is not necessary to make one rule for daytime use and one for nighttime. Put the daytime SID above the nighttime SID in the project file, and a single rule to override the default at night.

5.3.6 Set Parameters

Delayed aircraft and long queues are a major factor in slowing simulation execution. If these parts of the simulation are not important to your final results, you can frequently speed up the simulation by judicious choice of unimportant parameters.

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For a ground study, sometimes the terminal airspace is a limiting factor in throughput. You can frequently model this with a very small separation standard in uncontrolled airspace and a default sequencing interval set above zero. The result is a realistic flow with little additional computation overhead.

For an airspace study near an airport with complex runway configurations, sometimes you need to include a ground model to include the effects of, for example, taxiing aircraft that must cross an active runway. But a ground model in TAAM contains many gate management features that are not important to an airspace study. If you set all the gate occupancy times to the minimum value you will see a great increase in speed, without sacrificing the important features.

5.4 Randomization and Replications

In any computer simulation it is advisable to perform multiple runs with small variations in the input data in order to remove any sensitive dependence on initial conditions. If you perform multiple runs with randomized input, you can obtain a better understanding of the system under study, and your client can have more confidence in the results.

5.4.1 Randomization in the Design Phase

An airport or airspace design is based on nominal performance characteristics of the types of aircraft expected. In practice, the natural variations in aircraft weight, weather conditions, and pilot reactions may reveal flaws in the design. This feature of the real ATM system is well reproduced in TAAM – three areas where it is particularly important are SID/STAR design, runway exit usage, and departure capacity.

- **SID/STAR design**. SIDs or STARs developed in IDIS may be unflyable in the simulation, causing screen alerts. If the alert is ignored, erratic aircraft trajectories may result. When a SID causes alerts, it is generally the result of mixing instructions based on altitude with instructions based on DME from the departure airport. Randomization of aircraft climb rates makes sure your SID design is robust enough to handle all types of traffic. STARs are less problematic; descent rates may occasionally be too steep for some aircraft, but IDIS generally catches these.

- **Runway exit usage**. You can uncover possible problems with taxiway usage, when fast, heavy arrivals are unable to make the expected runway exit. This may be a sign that the taxiway centerline is not properly placed, or that other airport parameters may need adjusting.

- **Departure capacity**. Departure capacity of an airport is heavily dependent on the details of how aircraft climb out and turn. Separation exists when the aircraft are on diverging courses (by a number of degrees specified in sep_stand.dat). Most departure procedures are designed to take advantage of this. If the simulation is run in a deterministic mode, all aircraft on the same SID will be in trail, and radar separation may not be invoked reliably.

5.4.2 Multiple Replications of a Simulation

The order in which aircraft arrive or depart has an influence on the arrival and departure capacity of an airport. The ground speed of the leading aircraft at a meter fix or on a SID or STAR determines the ground speed of the trailing aircraft. In some cases, these sensitivities can affect simulation results. That is why running with randomized aircraft performance and a set of seeds is important. (In the instances above, randomization was useful even with a single run of the simulation.) TAAM is no different from any other simulation in the way runs are combined, so no further discussion of this topic is necessary here.

5.5 Using TPG Support

With TAAM, as with any simulation, you will encounter problems you did not expect. Sometimes the fixes for these are very simple and straightforward but often times a little research is involved in pinpointing and rectifying the problem. The TAAM reference guide can usually shed light on the most common problems so you should start your research there. If after you have researched the problem in the reference guide and tried your own solutions you still cannot fix the problem you should consider calling TPG to get some suggestions from them. They can usually get you started again in the right direction and offer some suggestions for you to try to resolve the problem.

If TPG cannot help you resolve the problem over the phone they may ask you to send your project to them so they can take a look themselves. The best way to do this is to use the TAAM tar function that is embedded into TAAM. Usually TPG asks that you to post your project to the TPG ftp site but they may request it on a cd or a zip disk.

Section 6

Working With TAAM Output Reports

This section applies most directly to Task 21, "Make Production Runs" shown in Figure 2-2*, "Task Flow for a TAAM Study" but is also relevant to any place in the entire process where you execute the TAAM simulation and examine output. These additional places are: Task 10, "Run Early Test"; Task 12, "Confirm Modeling Feasibility", Tasks 14 and 17 (Model Development, Phases I and II); and Task 20, "Conclude Model Development".

6.1 Preparations and Checks

When the final validation is complete, it is time for you to execute the final production runs. Here is a list of items to check:

- Each alternative scenario is contained in an appropriately named TAAM project

- Project settings meant to be common to base and alternatives are in fact the same

- Project settings meant to be different in the base and alternatives are in fact different

- All the TAAM simulations run to completion without error conditions

- There is sufficient disk space to contain all the projected output

- All unnecessary reporting options are turned off (to conserve disk space)

- Any multi-runs have the appropriate randomization parameters file checked

- The computer running any batches of simulation is protected from interruptions

You may want to adopt a formal approach to the production runs. Table 6-1 shows a sample checklist from the TAAM Study Database as developed by TPG which you can use as a starting point in tailoring a checklist for a particular project.

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* Figure 2-2, "Task Flow for a TAAM Study" is a three-page foldout at the end of this document.

Table 6-1. Checklist for a Production Run

Task Description	Done?	Notes	Post-It	Responsible
Check that all required scenarios have been fully built	☐			
Set up the batch	☐			
Check that correct reporting options are enabled	☐			
Conduct test run(s) of the batch	☐			
Verify that all simulations are completed	☐			
Load each report, go through checklist --->	☐		Checklist_Single	
Load multiple comparable reports, go thru checklist --->	☐		Checklist_Multiple	
If all OK, process output for required charts etc.	☐			
Refine simulations as needed	☐			
Complete Draft Final Report	☐			
Create TAR files for all projects, save to repository	☐	New set of TAR files (do not delete previous TARs!)		
Verify simulation results with customer	☐			
Make corrections as needed	☐			
Re-run batch, produce final simulation reports	☐			
Create final TAR files, save to repository	☐	These will go on the CD-ROM		
Produce, print Final Report	☐			
Prepare the PowerPoint pres. to customer if required	☐			
Burn the CD-ROM, print label	☐		CD-ROM contents	
Finish, populate the complete Study Database	☐	Include "ALL" materials related to study		
Deliver Final Report & CD-ROM to customers	☐			
Conduct post-study discussion within team	☐	"Lessons learned"		
	☐			

When you need to run multiple models, consider running TAAM with a Unix batch file. "Running TAAM Overnight in Batch Mode" is covered in chapter 3 of the *TAAM Practical Guide*. When running in batch mode remember that

- TAAM will run with *no* graphics in batch mode, and

- If multi-runs are requested, TAAM will automatically enable randomization even if the user turned off this option (on the assumption that is why you want to run multiple iterations of the same project).

6.1.1 Post Run Checks

It can be helpful to run a test batch first (say, overnight) and then inspect the TAAM Log file first thing in the morning. Remember to do this before you run the next simulation that will overwrite the TAAM Log.

The critical information you want from the TAAM Log is whether all the simulation runs have completed. A way to do this is to use the UNIX *grep* command in your TAAM working directory to search for the word *Project*:

```
grep Project TAAM_Log
```

You will see the output similar to this:

```
Project [name1]: STARTED [date and time]

Project [name1]: FINISHED [date and time]

Project [name2]: STARTED [date and time]
```

```
Project [name2]: FINISHED [date and time]
```

If not every STARTED line is followed by FINISHED, then you have a problem. You need to examine any culprit projects and re-run them.

6.1.2 Output File Check

After making your model runs, list the report directory,

reports/[username]/[any_subdirectory]

and make sure that all the output files, such as *[project].rep, [project].sum, [project].msg* from all runs are present and have comparable size. Significant size differences may be caused by:

- Unfinished simulation runs (TAAM crashed or simulation ended prematurely because the End Time was set too early);

- Unnoticed differences in simulation options (a very important mistake to catch); or

- Differences in reporting options.

After checking the sizes of the output files, open the TAAM RPF and load all the report files. If there is a large number of report files, loading them in groups in order to make a thorough check on the statistics. Here is a sample task list for checking the model statistics:

- Load the base case report and the alternative case reports .

- Make sure that the time interval is the same for all projects. It is often better to set it explicitly via "Edit Variables" panel rather than using the default "Start/End of Simulation" setting, because different projects may have slightly different start/end times which makes it difficult to overlay different reports.

- Set "Presentation" to "Graphs".

- For each comparison that you're going to make, take the following actions to ensure that different types of reports will have the same line color or type (in printout) assigned to the same TAAM project

Disable the "Overlay Reports" option

Highlight the Base Case project in the list of loaded projects;

Select "report type" to show the graphs for your base case;

Enable the "Overlay Reports" option;

Highlight the first alternative from the list of loaded projects so you can see the overlaid graphs;

Continue to load other alternatives (note: you can overlay up to five different graphs).

- Start with the default 30-min time intervals before investigating other intervals

- If you have modeled a major airport, select "Airport Movements / Departures" and compare the reports. Watch for any noticeable discrepancies between movement rates and make sure you can be explain them.

- Repeat the same for "Airport Movements / Arrivals".

- Repeat the same for "Departure Delays". If major discrepancies are found, you may want to go deeper by checking delays by "Source".

- Repeat for "Arrival Delays".

- If you studied airspace, check "Sector Movements".

- If you analyzed conflicts, check the "Aircraft Proximity Monitoring and Conflict Check" reports.

Make a thorough investigation of any serious questions and doubts that arise during any of these comparisons. The "Checklist for Multiple Cases" shown in Table 6-2 is an attempt to provide a framework for comparison between different scenarios. It should help you spot any suspect runs with statistics being very different from the rest of the scenarios.

Table 6-2. Checklist for Multiple Cases

Task Description	Done?	Notes	Responsible
Compare Airport Delay Distribution / Departures	☐	By source if needed	
Compare Airport Delay Distribution / Arrivals	☐		
Compare movement rates (10, 15-min intervals)	☐	Separately for Arrivals and for Departures	
Use the "same" order for all multiple report graphs	☐	Overlay: NO, select 1st file; Overlay: YES, add other files	
Compare conflict counts in sectors	☐	If studied	
Explain, investigate any suspect differences	☐		
Decide when to produce Taxi-In, Taxi-Out times	☐	Use available Excel macro!	
Compare Delay Per Aircraft for consistency	☐	E.g. IFR > VFR, higher traffic levels = higher average delay etc.	
	☐		
	☐		

6.1.3 Checking TAAM Report and Summary Files

In the TAAM Report file:

- Locate the "Flight Summary So Far" line with the latest time-stamp. Check this part of the file for rejected and terminated flights.

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In the TAAM Flight Summary file:

- For each TAAM project, take the first 20-30 flights (that is, those having the most delay) and compare their delays and overall block times;

- Check the "Average Delay" value. Some consistency in the average overall delay across all simulation runs for the study is to be expected, although this parameter may be too general for you to draw any far-reaching conclusions.

6.2 Output Data/Reports

Once you have confidence in the output from the TAAM discussed above, you can proceed with any additional post-processing. One frequent post-processing task is to calculate any metrics not available directly from the RPF, such as the average taxi time at an airport. Another post-processing task is to create informative graphics to help communicate the results of the TAAM study.

Section 7

Presenting the Results of a TAAM Study

This section applies to every task where you will present TAAM results to an audience, including Task 16, "Hold Preliminary External Validation Meeting", Task 19, "Hold Final External Validation Meeting", Task 23, "Document Project" and Task 24, "Conclude the Project" shown in Figure 2-2[*], "Task Flow for a TAAM Study".

7.1 Presentation Format

Tailor your briefings for your intended audience and the expected outcome of your presentation. For example, the intent of your presentation may be to verify airspace or procedure assumptions, present intermediate results, or present final results. Remember that your audience may have detailed knowledge of the airspace of concern and varying levels of TAAM knowledge.

Include several or all the following components in your presentation depending on the stage of the study:

- The study design statement

- The airspace and airport surfaces represented in the base and alternative cases

- What procedures are represented

- The simulated air traffic

- The simulated weather conditions

- The definition of the study metrics

- Validation activities

For intermediate and final result presentations include any results from detailed metrics analysis and describe how the base case was validated. In these presentations you may also include either a detailed TAAM demonstration, or use of TAAM movie clips as part of a Microsoft Power Point presentation.

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[*] Figure 2-2, "Task Flow for a TAAM Study" is a three-page foldout at the end of this document.

7.1.1 Briefing Preparation

The essential homework for the person conducting the presentation, is to know and understand the object of the study (airport, airspace), know and understand the study assumptions and conclusions. The audience can be quite diverse and may well want explanations of "how things work" in TAAM and the strengths and limitations associated with any TAAM study.

The most important aspect of your presentation is your ability to show plausible simulation output numbers and be able to explain each one of them in full. If TAAM shows an average arrival rate of 80 per hour, you must be sure that in the given airport conditions, this is a rate that one can expect. Or, if there is a higher number of conflicts in a sector, you must be ready to demonstrate what caused it (other than an error in your procedure setup, which is an unsatisfactory reason).

You want to show good individual numbers and also make sure that comparisons of these numbers makes sense. For example: if in one configuration two independent runways are open for arrival and, in a different configuration, three runways are open, but two of them are dependent, you need to be able to give a thorough explanation of the difference in flow rates.

The cross-checks you present should include the same metrics for different scenarios and also different metrics for same scenario. For instance, if there is a higher average delay per flight, that should be reflected in longer taxi times (and you must be able to explain why they are longer by this much), or lower departure/arrival rates.

If, during the preparation of the study report, the numbers look suspect, postpone the presentation to allow for further analysis. It is better to delay the presentation than to go before the client with questionable numbers.

7.2 Report Format

7.2.1 Study Report Preparation

An example sample report template is provided below.

1. Executive Summary

2. Background (Problem Characterization)

3. Study Overview

    (a) Objectives

    (b) High Level Approach

    (c) Schedule

    (d) Roles and Responsibilities

4. Input Data Preparation and Key Assumptions

   (a) Input data preparation

   (b) Key assumptions

   (c) Scope of the study

   (d) Runway use

   (e) Runway allocation

   (f) Terminal airspace

   (g) SIDs, STARs, Final Approach

   (h) En route airspace

   (i) Traffic flow management

   (j) Gates, aprons, parking positions

   (k) Taxiing, lineup for departure

   (l) Runway exits, runway crossing

5. Project TAAM Base Case

   (a) Special technology or procedures relevant to study

   (b) Base case development

   (c) Base case calibration metrics and tolerances

   (d) Base case calibration results

6. Study Alternatives Development

   (a) Scenarios studied

   (b) Alternative A analysis

   (c) Alternative B analysis

   (d) …

   (e) Alternative N analysis

7. Study Conclusions

   (a) Appendix A: TAAM Definitions and Output Metrics

   (b) Appendix B: Glossary

7.2.1.1 Report Size and Details

Points to remember while preparing the final report:

- While the final report size is dictated by the scope of the study, the document should be detailed enough to list all assumptions, describe the base case preparation and validation, describe the preparation of alternative case scenarios, their analysis (by themselves and compared to other scenarios), and the study conclusions.

- Use graphics anywhere they will enhance your arguments. Include airport or airspace diagrams, charts or plots of TAAM output, TAAM screen snapshots and so on. When you create a TAAM screen snapshot, select the picture carefully; avoid cluttering the screen, make sure that the picture illustrates your point clearly.

- Convert TAAM outputs into color charts, in Excel or other graphing tool., or attach TAAM report printouts from the RPF as an appendix.

If you include a CD-ROM as part of your report, here is a suggested template for the CD table of contents:

- Non-TAAM Input Data Files

  – Airport layouts in electronic form (AutoCAD or other)

  – Scanned airport or apron layout diagrams, with gate allocation and taxipaths marked using color markers

  – Videomaps for airspace

  – Files from other airspace design tools such as Sector Design and Analysis Tool (SDAT)

  – Scanned airspace layout diagrams, with SIDs and STARs marked using color markers

  – Traffic samples: ETMS/Aircraft Situation Display (ASDI) to Industry, OAG, airlines' proprietary schedules

  – Any other input data in non-TAAM format

- Project Related Documents

  – Meeting minutes

  – Statement of Work for the project

  – Final Report

  – Related PowerPoint or other such presentations, including all pictures or TAAM movie segments referenced to in the presentations

- – Base case validation documents

- – Other relevant correspondence: important emails, clarifications, requests etc.

- TAAM TAR Files

  - – TAR files for *all* TAAM scenarios including the base case, arranged in sub-directories if required

- TAAM Study Database

  - – Completed TAAM Study Database for this project

- TAAM Outputs

- All TAAM primary outputs: Report (*.rep), History (*.hst), Summary (*.sum), GFDR (*.gfdr) files, arranged in sub-directories if required

  - – All secondary outputs obtained by processing the primary outputs: Excel spreadsheets, database files etc.

- TAAM (sim.sun4) Executable

  - – The sim.sun4 executable with which this study was completed

- Other Files

  - – The picture files used for the production of this CD label.

Section 8

Reviewing a TAAM Study

This section is different from the others in this document because it is addressed not to a TAAM simulation analyst, developer, or manager, but to a potential client or reviewer of a TAAM study. Because TAAM is designed for studying complex problems, it is complex itself and can be very confusing to anyone working with it for the first time. Here is a checklist of points to consider when reviewing a TAAM simulation project.

8.1 Checklist

- What is the study **objective**?
  - Is this objective clearly stated in project briefings and the final report?
  - If the definition of the objective changed in the course of the study, are the changes fully documented?
- What **metrics** are identified as bearing on the study objective?
  - Are these metrics appropriate for the study objective?
  - Is the definition of each metric explained in briefings and the final report?
  - Is it clear how each metric is defined relative to TAAM simulation output?
- Is there a clear statement of the geographical and temporal **scope** of the study?
- Is each **alternative** case studied in this study clearly defined?
  - Is the motivation for including each alternative adequately explained?
- Is there a clear description of the modeling **assumptions** that hold for each case studied in the study?
  - Do the assumptions make sense?
  - Are there any missing assumptions that might affect the study results?
- Are the **data** sources used for this study adequately identified?
- Is the **validation** process adequately described?
  - Have the study input data been validated?
  - Has the definition of the TAAM simulation for each alternative case been validated?

- Are the study **results** clearly explained?

  − Are the results logically consistent?

- Do the study results support meaningful conclusions?

Appendix A

An Overview of Fast Time Simulation

Many decisions in the aviation industry involve high stakes. Infrastructure investment, such as a new runway or terminal, can cost billions of dollars. New aircraft run into the tens of millions of dollars. Even decisions that don't involve an aircraft purchase or a construction project, such as a change in an airline's schedule or an air traffic control policy, can have a large impact on customer service and an airline's bottom line.

The complexity of an aviation system, however, can make evaluating the impact of different alternatives very difficult. In most instances, it is impractical, expensive or dangerous to experiment with the different alternatives using real planes, pilots, and airports. Instead, it is usually simpler to build a model of the system.

Because of system complexity, valid, useful models of the system will often be complex, too, so a computer will be needed to run the model. Ideally, we can make models of the various alternatives we want to consider, and use a computer to evaluate each alternative.

A fast-time simulation is a computer model of a real system built for the purpose of better understanding system behavior or for evaluating different system designs or operation strategies. A simulation model mimics the fundamental behaviors of the real system as they change over time, and should be able to predict how changes to the system will affect that behavior.

A.1 Different Categories of Simulations and Simulators

To avoid confusion about what a *fast-time* simulation is and does, we compare fast-time simulation to two other simulation methods that may be familiar to people working in the aviation industry.

A.1.1 Real Time, Look-Ahead Simulations

Some traffic monitoring simulations use live real-time data feeds to assess the current state of a system, then simulate ahead from that point to predict what the situation will be in the near future (30 minutes or 2 hours later). These simulations support tactical decision-making, for instance, how many flights should be moved from one route to another, or which flights should be delayed or cancelled.

A.1.2 Human-in-the-Loop Simulators

The goal of these simulators is to recreate a scenario in an operational environment, and to test how human participants cope with their tasks. The simulators allow human interaction, that is, human input influences the direction that simulated events will take. This sort of simulator can be used to train and test air traffic controllers for unusual or dangerous

situations that may arise. Flight cockpit simulators, such as the ones used by pilots, also fall under this category.

A.1.3 Fast-Time Simulation

A fast-time simulation is used for planning, design, and "what-if" analysis. It is for more strategic, long-term decisions than for short-term tactical decisions. Fast-time simulation does not have a "human-in-the-loop;" all of the logic is coded into a computer program. A fast-time simulation does not use a live data feed; it takes some fairly simple flight data from a file, and then lets the logic of the computer program calculate exactly where and how quickly the flights are supposed to go. The term "fast-time" comes from the fact that simulated time moves more quickly than real time, allowing an entire day to be simulated in a matter of minutes or hours.

A.2 Fast-Time Simulation in Other Industries

Fast-time computer simulation is a time-tested method used in industries other than aviation. Most prominently, simulation is used in manufacturing environments to evaluate new work-flow designs on factory floors and work allocation among stations. In manufacturing, some of the primary concerns are cycle time (the start-to-finish time required to make a product) and required parts inventory levels. In the service industry, simulation is used to evaluate such things as the design of fast-food restaurants, where the metrics of interest are customer service times and time spent in queue (waiting line). In the healthcare industry, simulation is used to model the design of emergency rooms and hospital admissions procedures. Outcome measures in this setting include the availability of beds in different wards, and the wait time in hospital emergency rooms.

A.3 Simulation Language and Packages

At its heart, a simulation model is a computer program. It is possible, but extremely time-consuming, to write an entire simulation model in a *general-purpose* programming language such as C, C++, or FORTRAN. Fortunately, software developers have written simulation *packages* tailored specifically for simulation modeling, which greatly reduce the amount of programming work required by the simulation modeler. As a result, the simulation developer can build a mode with minimal knowledge of computer programming. Some simulation packages also make simulation projects easier by automatically collecting important output statistics, and providing animation of the working model. TAAM is a simulation package that is specifically designed for modeling aviation traffic in airports and in the airspace. Other simulation packages are specifically designed for manufacturing settings and the healthcare industries.

A.4 Animation/Visualization

As mentioned above, simulation packages such as TAAM often provide the user with the ability to animate the model. Animation is an important tool for the following reasons:

- Animation greatly enhances the credibility of a simulation model by communicating the essence of the model. It is much easier to get a feel for the model through animation rather than through strictly numerical output.

- Animation is critically important for model validation; people who are knowledgeable about the airport or airspace, but are unfamiliar with simulation, can watch the animation and determine if the model adequately and accurately represents the important features of the system.

- Animation is also very important for model debugging and verification. The simulation developer can often find out directly if the model is doing what he/she intended by watching the animation.

- Under some circumstances, animation can also be used to help train operational personnel (such as air traffic controllers) by illustrating new procedures.

One pitfall of animation is that it may tempt the modeler into making an overly detailed model just for the sake of creating a good-looking animation. The way to avoid this problem is to keep the overall project goals in mind, and resist the temptation to model and animate non-essential detail.

A.5 Uses of Fast-Time Simulation

Fast-time simulation can help planners and designers in a number of different ways, several of which are listed below.

- **Choose the Best Alternative**. Simulation allows one to make a thorough test of different design plans before implementing one of them. For example, if an airline is contemplating adding four new gates at a terminal in an effort to reduce congestion, one can develop a simulation model to test how many new gates will be required. A simulation study might reveal that adding new gates will not alleviate congestion, because runway capacity is the real constraint. On the other hand, the study might show that only two gates, rather than four, are necessary to reduce congestion to a reasonable level. In either case, the information gained from the simulation study can help to make sounder decisions.

- **Expand or Compress Time**. A fast-time simulation allows one to run an entire period of simulated time, be it a day, a month, or a year, in a matter of minutes or hours. This short turn-around time allows new designs to be evaluated relatively quickly. On the other hand, one could also slow down the simulation to allow a very detailed study of the events of a short period of simulated time.

A-3

- **Explore possibilities**. Once a model has been developed, it is often relatively easy to change the model to gauge the effects of new ideas, such as different taxiway routings or runway assignment rules. One compares the results of running the altered model to the results with those from the original model and looks for differences to the output resulting from the changed input.

- **Do "What if" analysis**. Many changes faced by an aviation system (such as an airport or terminal area) are not the result of design or policy changes, but are due to other factors outside of the designer's control, such as an increase in demand, or the onset of poor weather. A simulation can help to determine the effects of such changes before they occur, and may help to suggest design or policy changes that will allow the system to fare better when uncontrollable changes occur.

- **Diagnose problems and identify constraints**. Because aviation systems are so complex, it can be extremely difficult to predict problems that might result from a proposed change or design alternative. For instance, it may not be obvious that a particular set of taxiway routings combined with a particular arrival push will cause the airport to gridlock. A simulation can help by pointing up such unexpected problems.

- **Visualize the plan**. A simulation model can be animated on screen to allow designers and decision-makers to see a proposed system "in action" before it is actually implemented. TAAM has a very sophisticated animation interface that is a critical tool for model design and validation.

- **Specify requirements**. A simulation can help us to determine the capacity necessary to meet desired goals. For instance, if we want an airport to handle a certain number of flights per day, and we want total time spent waiting for a gate to be under a specified threshold, how many gates will we need?

A.6 Limitations of Fast-Time Simulation

Although fast-time simulation is a very useful tool, it has its costs and limitations.

- **Model building requires special training**. Simulation modeling requires specialized skills, training, and experience. The quality of the study depends in large part upon the quality of the model and the modeler. It is also important that the modeler have a good understanding of the system in question.

- **Simulation modeling and analysis can be time-consuming and expensive**. There are several important steps in a simulation study. One must formulate the problem to be solved, set objectives and a project plan, develop a conceptual model, gather input data, write the computer model, verify and validate the model, and perform analysis on the output. These steps can consume a great deal of time and work. Before

embarking on a simulation study, one must decide if the time and cost are worthwhile.

- **Simulation is an evaluative tool, not an optimizer**. Simulation can be used to *evaluate* different design alternatives, but it does not *generate* different alternatives or automatically return the best alternative. In other words, simulation is not an optimization tool. If one wants to compare different alternatives, one has to design a simulation model for each alternative, run them separately, then compare the simulation output (for example, throughput and delay metrics) to determine which one is the best.

A-5

Appendix B

Developing Flight Schedules

One of the most fundamentally important aspects of any simulation is the event schedule. In TAAM, this takes the form of a traffic schedule which embodies as much information about the simulation and affects the results of the simulation as much as any other aspect of the simulation. Therefore, it is important that the source of the traffic schedule be reliable, and the implications of any modifications made to it be understood.

If ETMS Data is the Only Source

Enhanced Traffic Management System (ETMS) data is based on Zulu time – keep this in mind if you are preparing a terminal airspace study. If time-of-day related features need to be taken into consideration (for example, daytime start/end at the hub airport, noise modeling where distinction between night and day is important), then the schedule needs to be converted into local time. TPG has developed a script that shifts all times in the timetable by the specified number of hours.

If ETMS is Used with OAG Data

This is a much more complicated situation because:

- OAG data contains city pairs only whereas ETMS/ASDI data has full flight plans;

- OAG uses IATA airport and airline codes whereas ETMS/ASDI uses ICAO codes (for example, London Heathrow IATA code is LHR while the ICAO code is EGLL; United Airlines IATA code is UA while the ICAO code is UAL);

- OAG uses local time for ETD/ETA whereas ETMS/ASDI uses Zulu time.

OAG Conversion Process

The process of converting OAG data is presented below. The auxiliary tools mentioned in this process were available on the TPG Website at the time of writing.

Step 1: Navigate to the directory where the original OAG data resides:

> **cd** *directory*

Step 2: Run the tool "dos2unix" conversion on OAG data file:

> **dos2unix** *OAGfilename > newfilename*

Step 3: Manipulate the OAG data file as necessary: amend aircraft callsigns, aircraft types, market segments, etc. using a Text Editor on *newfilename.*

Step 4: Run the tool "*iata2icao.sun4*" conversion:

iata2icao.sun4 *newfilename* IATAICAO. list *newfile1.ACF*

Step 5: Next run the TAAM OAG converter on *newfile1.ACF*

> **Open TAAM main screen**
> **Open External Data Conversion**
> **Type in the Airport name**
> **Type in or select the Preferential Route File name**
> **Choose Month, Day, Year, # of Days**
> *Write Both ETD and ETA* **option: set to No**
> **Input File is *newfile1.ACF***
> **Output File is *newfile2.ACF***
> **Run Convert**
> **View Output File for accuracy**

> Note 1: The resulting timetable (*newfile2.ACF*) is comprised of city pairs only. For some applications, this will be satisfactory. If you need additional accuracy for SID and STAR use, however, TPG has a converter named *add_waypt.sun4*. This file requires additional manipulation to correct two letter air carrier identifiers (OAG format) to three letter identifiers (Industry standard), if necessary.

> Note 2: This data is also provided in local time. TPG has a converter named *timechange.*

Step 6: Add supplemental traffic from ETMS or other sources

> Note: Supplemental traffic can come from a variety of sources. If ETMS data is used, you must ensure that the OAG traffic and the ETMS traffic is not duplicated.

> **Open IDIS**
> **Merge timetables *newfile2.ACF* + *ETMSdata.ACF***
> **Resulting file is *newfile3.ACF***

Step 7: Use IDIS to check *newfile3.ACF* for errors

Select *newfile3.ACF* file and List/Edit action
Run Check

Step 8: Correct any reported errors

Glossary

ACF	(file extension designator for the TAAM flight schedule file)
ARTS	Automated Radar Terminal System
ASDI	Aircraft Situation Display
ATC	Air Traffic Control
ATM	Air Traffic Management
CAASD	Center for Advanced Aviation System Development
COTS	Commercial Off-The-Shelf
CPU	Central Processing Unit
ERAU	Embry-Riddle Aeronautical University
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
FLAS	Flight Level Allocation Scheme
GA	General Aviation
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
IDIS	Interactive Data Input System (in TAAM)
IFR	Instrument Flight Rule
IMC	Instrument Meteorological Conditions
MIT	Miles In Trail
NAS	National Airspace System
OAG	Official Airline Guide
RPF	Report Presentation Facility (in TAAM)
RVSM	Reduced Vertical Separation Minima

SAR	System Analysis Recording
SDAT	Sector Design and Analysis Tool
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival Route
TAAM	Total Airspace and Airport Modeller
TPG	The Preston Group
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omnidirectional Range
VV&A	Verification, Validation, and Accreditation

Task Flow for a TAAM Study

Task Flow for a TAAM Study

1. Identify Resources

1a. The Team	1b. Hardware and Software Resources

2. Hold Internal Kickoff Meeting

3. Investigate Study Background

3a. Physical Infrastructure	3b. Procedural Issues	3c. Stakeholders

4. Hold External Project Kickoff Meeting

5. Develop Approach

5a. Preliminary Study Design Statement Revisit and develop until task 15.	5b. Coordinate Project Conventions

6. Create File Structures

6a. Project Directory	6b. Project Specific Data Directory

Figure 2-2

7. Build Preliminary First-Level Input Files

| 7a. Timetable *** | 7c. Sectors | 7e. Simulation Parameters and Options |

| 7b. Weather and Winds Files | 7d. Background Maps | 7f. Airport Layouts *** |

8. Build Preliminary Second-Level Input Files

| 8a. Waypoints Airports Routes | 8b. Airport Usage SIDs STARs *** |

9. Build Preliminary Base Case Project File

10. Run Early Test

11. Build Alternative Case Project Files

12. Confirm Modeling Feasibility ***

| 12a. Base Case Experimentation | 12b. Alternative Cases Experimentation |

13. Reassess Study Design

| 13a. Definitive Study Design Statement | 13b. Outline for Final Report |

14. Execute First Development Cycle

Base Case

- Augment and Correct Data
- Update Model
- Generate Output
- Verify
- Make Archive

Alternative Cases

15. Prepare for Preliminary External Validation

16. Hold Preliminary External Validation Meeting

17. Execute Second Development Cycle

Base Case

- Augment and Correct Data
- Update Model
- Generate Output
- Verify
- Make Archive

Alternative Cases

18. Prepare for Final External Validation

19. **Hold Final External Validation Meeting** ***

20. **Conclude Simulation Development** ***

- Update Model
- Verify

21. Make Production Runs

22. Calculate Metrics

23. Document Project

24. Conclude the Project

24a. Delivery

24b. Final Archiving