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The Combination of Flight Count and Control Time as a New Metric of Air Traffic Control Activity

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16. Abstract

The exploration of measures of airspace activity is useful in a number of significant ways, including the establishment of baseline air traffic control (ATC) measures and the development of tools and procedures for airspace management. This report introduces a new metric of ATC activity that combines two existing measures (flight count and the time aircraft are under control). The Aircraft Activity Index (AAI) is sensitive to changes in both flight count and flight length, and therefore is a superior measure for comparing aircraft activity between two epochs of time. The AAI was applied to data from 10 days of System Analysis Recordings obtained from the Seattle Air Route Control Center. The advantages of the AAI were most apparent when different aircraft types consistently had different mean flight lengths. Possible uses of the AAI and other ATC measures for the evaluation of new systems and procedures are discussed.

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THE COMBINATION OF FLIGHT COUNT AND CONTROL TIME AS A NEW METRIC OF AIR TRAFFIC CONTROL ACTIVITY

INTRODUCTION

An important aspect of the evaluation of new air traffic control (ATC) systems is the comparison of current systems and procedures with proposed ones. A relevant factor in making these comparisons is the level of various activities occurring in a specified unit of airspace during a defined period of time. This process has been conceptualized in different ways, with the use of such terms as controller workload, airspace complexity, and dynamic density. In general, however, the studies conducted in this area have included measures of controller actions, aircraft dynamics, and sector characteristics.

The exploration of measures of airspace activity is useful in a number of significant ways. These include the establishment of baseline ATC measures, as well as the development of tools and procedures for airspace management (See Galushka, Frederick, Mogford, & Krois, 1995, and Pawlak, Bowles, Goel & Brinton, 1997, as examples). The establishment of baseline measures is necessary for evaluating any changes resulting from the introduction of new ATC systems or procedures. Significant modifications have been proposed for the United States' National Airspace System (NAS; FAA, 1997). The NAS Architecture is the Federal Aviation Administration's (FAA's) comprehensive plan for modernizing the infrastructure of the NAS. Version 2.5 of this plan calls for significant changes in the interactions between air traffic controllers and pilots, incorporating the use of updated navigation, surveillance, and communication equipment and corresponding procedures. The impact of these modifications on the NAS will need to be assessed by researchers. Toward this goal, the establishment of baseline measures will allow airspace activity, measured under the current system, to be compared with activity assessed after new systems and procedures have been introduced. These comparisons will quantify any changes resulting from the implementation of new systems. As a simplified example, if a new set of procedures designed to reduce handoff activity were introduced to an ATC facility, the effectiveness of the procedures could be assessed by comparing measures of handoff activity collected before and those collected after the implementation of the changes. The amount of reduction, if any, of handoff activity would indicate the effectiveness of the new set of procedures.

Another important use of airspace activity measures is for the development of tools for more effective airspace management. Currently the FAA performs an annual review of all en route sectors by using a complexity workload formula (FAA, 1984). This formula is designed to be applied to data from peak traffic time periods and to be used to establish or adjust sector configuration. However, the need for *dynamic* activity assessment, i.e., real-time measurement, is emerging with the aviation community's move toward the operational concepts collectively known as "Free Flight."

Free Flight refers to the proposed revision of the NAS from a centralized system, in which air traffic controllers assign aircraft to routes, to a distributed system that allows pilots more freedom to select their own routes and altitudes. Under Free Flight, pilots presumably will assume more responsibility for maintaining separation from other aircraft than they have under the current system. The changes included in Free Flight are considered to be necessary because of the limitations of the current system, the significant increases projected for air traffic, and desired improvements in efficiency for airlines. RTCA, Inc., an organization that addresses requirements and technical concepts for aviation and functions as a Federal Advisory Committee, has performed much of the planning for Free Flight. The Final Report of RTCA Task Force 3: Free Flight Implementation (RTCA, 1995), emphasizes the need for the FAA to develop a method of assessing *dynamic density*, or "the projected workload and safety of future traffic in an operational environment." Under Free Flight, this assessment process could drive the dynamic reconfiguration of sectors, thus increasing the capacity and operational efficiency of the NAS. The RTCA report contends that this type of capacity management is essential to the Free Flight concept.

Several studies (cited below) have explored airspace activity in various ways. The methodology most often used assumes that many variables affecting activity in an airspace also influence the perceived workload and the objective task performance of the controller. For example, as the flight count in an airspace increases from an average number to a high number, one might expect the controller to perceive a higher workload level and to perform a higher number of objectively measurable activities to maintain effective control of the airspace. The variables used in such studies have been described with the terms workload, complexity, and dynamic density. Therefore, measures of subjective workload and of individual performance may be related to airspace activity, including workload, complexity, and dynamic density.

Buckley, DeBaryshe, Hitchner, and Kohn (1983) conducted a study consisting of a series of experiments in an ATC simulation environment and, as a result, identified a set of four general factors (Conflict, Occupancy, Communications, and Delay) and two auxiliary measures (Number of Aircraft Handled and Fuel Consumption) that appeared to adequately represent all other ATC measures. The authors recommended the use of these measures for subsequent air traffic simulation studies. Stein (1985) exposed controllers to different levels of airspace activity in another simulation experiment and concluded that three variables, Aircraft Count, Clustering, and Restricted Airspace, significantly influenced workload.

More recently, Mogford, Murphy, & Guttman (1994) used verbal reports from air traffic control specialists and multidimensional scaling to identify a list of 16 factors that contribute to airspace complexity. Pawlak, Brinton, Crouch, and Lancaster (1996) focused on controllers' strategies and decision-making activities; proposing a list of 15 factors that may influence perceived air traffic complexity.

Although the studies cited above used different conceptualizations and methods, most included methods of counting flights and/or the time aircraft were under control. While these measures are useful for assessing controller activity, it may be more informative to employ a measure that combines information about both the number of flights and the duration of control. In addition, it may be more useful to compute the measure separately for different types of aircraft in order to obtain a measure of airspace activity that is sensitive to differences in specific circumstances. Although the measure proposed here is only one of many that influence airspace activity, refinements such as this can add to our overall ability to quantify operational aspects of the NAS.

An ATC Aircraft Activity Index

This paper introduces a new metric of ATC activity that combines two existing measures (flight count and the time aircraft are under control) to produce a more informative metric than either measure provides when used alone. Given an epoch of airspace activity (e.g., all air traffic controlled by a certain ATC position during a specific period of time), two simple measures, (1) flight count, and (2) aggregate control time, can be combined to produce a measure of activity, the Aircraft Activity Index (AAI). By combining the two measures, the AAI accounts for some of the limitations of using each measure independently. Specifically, the product of the ratio of number of flights to total epoch time and the ratio of aggregate control time to total epoch time is a measure that is sensitive to both number of flights and length of flights within the epoch (See Equation 1). Ratios are used in the equation so that the measure is sensitive to the length of the epoch being evaluated.

Equation 1. Aircraft Activity Index

$$\text{Aircraft Activity Index} = \frac{\text{Flight Count}}{\text{Epoch Time}} \times \frac{\text{Control Time}}{\text{Epoch Time}}$$

Table 1 summarizes the relative advantages and disadvantages of the different measurement techniques. Flight count is sensitive to the number of flights controlled during a certain time period; however, it is not sensitive to the length of flights. Therefore, a simple flight count cannot distinguish between periods when most flights are relatively short and periods when they are relatively long. Although the aggregate control time measure is sensitive to the length of flights, it is not sensitive to the number of flights. Consequently, it can only distinguish between periods of short flight lengths and long flight lengths when the flight counts of both periods are similar. It cannot distinguish between a relatively large number of short flights and a relatively small number of long flights.

Table 1. Comparison of ATC Measures

ATC Measure	Advantages	Disadvantages
Flight Count / Total Time (F/T)	Sensitive to number of flights.	Not sensitive to length of flights. Short flights (less control activity) are not distinguished from long flights (more control activity).
Aggregate Control Time / Total Time (C/T)	Sensitive to length of flights.	Not sensitive to number of flights. Cannot distinguish between several short flights (more control activity) and fewer long flights (less control activity).
Aircraft Activity Index (F/T x C/T)	Sensitive to both number of flights and length of flights.	

The AAI combines information from flight count, flight length, and length of the time period being analyzed, and therefore reflects changes in all three metrics.

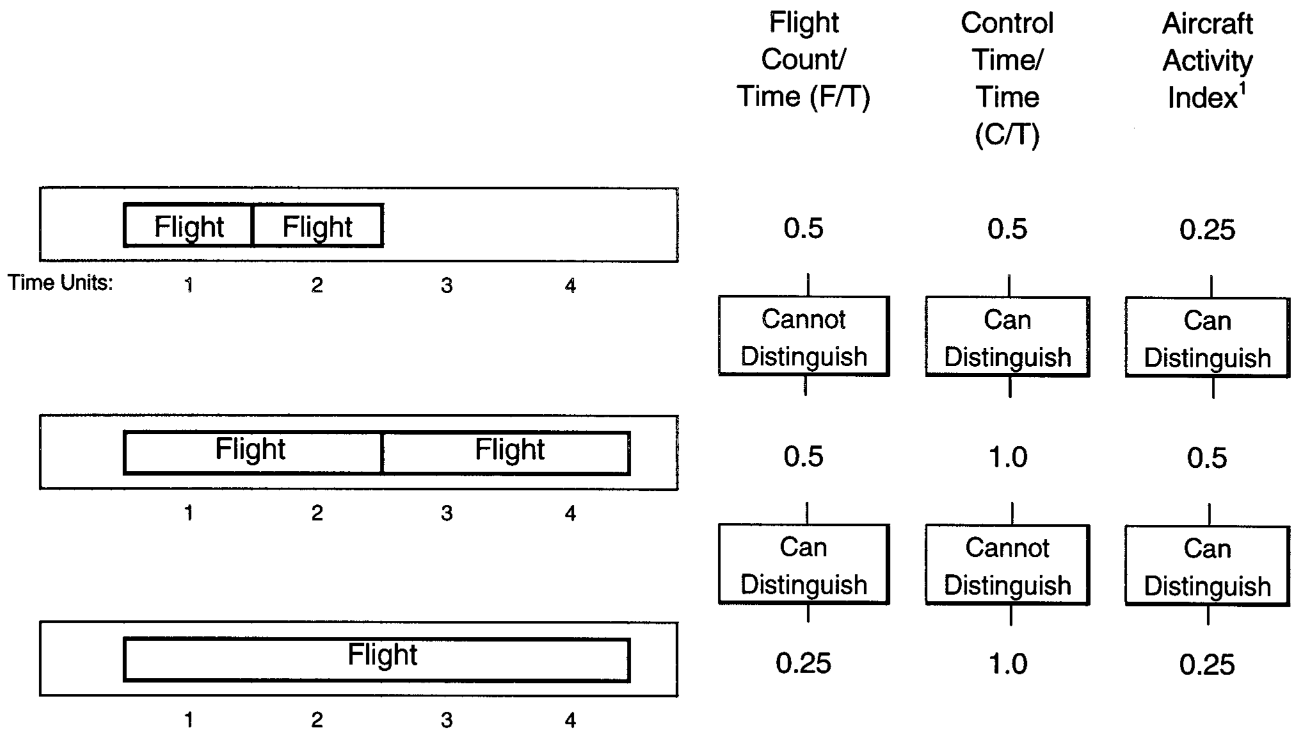
Figure 1 graphically demonstrates the different sensitivities of the measures when applied theoretically to different flight count-flight length combinations. Flight count cannot distinguish between two short flights and two long flights, even though the aggregate control time for the short flights is only half as long as that for the long flights. Flight count can, however, distinguish between two short flights and one long flight, even when their aggregate control times are equal. Aggregate control time can distinguish between two short flights and two long flights but is not sensitive to the difference between two short flights and one long flight. Unlike the simpler measures used alone, the AAI can distinguish between two short flights and two long flights *and* between two short flights and one long flight.

METHOD

Application of the AAI

Airspace activity should vary as a function of the type of aircraft controlled because different aircraft types have different characteristics that may influence their interaction with ATC. Aircraft performance characteristics are an important factor that must be considered by the controller when assessing potential conflicts or sequencing aircraft. One method of classifying aircraft according to performance characteristics is to distinguish between three types of engines: jet, turboprop, and piston propeller. Different types of aircraft also may require various levels of interaction with ATC, depending on their flight purpose and the types of navigation and communication equipment installed. These flights can be distinguished by classifying them into three categories: commercial, general aviation (GA), and military. For purposes of demonstrating the AAI, flights included in this study

Figure 1. Sensitivity of ATC Measures



[1] Aircraft Activity Index = (Flight Count / Epoch Time) X (Aggregate Control Time / Epoch Time)

were analyzed by aircraft type, with type being distinguished as one of the nine possible combinations of the above classifications. This resulted in the following nine types: Commercial-Jet, Commercial-Turboprop, Commercial-Piston, GA-Jet, GA-Turboprop, GA-Piston, Military-Jet, Military-Turboprop, and Military-Piston.

The AAI was applied to data from 10 days of System Analysis Recordings (SAR) obtained from the Seattle Air Route Traffic Control Center (ZSE). Selected data were extracted from the SAR recordings by the NAS Data Analysis and Reduction Tool (DART). A computer program, the NAS Data Management System, was developed to encode the text-based DART output reports into relational databases. An additional computer program analyzed the databases and identified and categorized aircraft types associated with each controlled flight.

Flight count was calculated for each defined epoch by counting all flights controlled by Seattle Center for at least 6 seconds (i.e., one update of the Track file produced by DART) during that epoch. Aggregate control time was obtained by adding the elapsed time of all such updates for every aircraft controlled by the Center during the epoch.

RESULTS

The Aircraft Activity Index (AAI) was calculated for each aircraft type for each of the 11 most active hours of the day (0600-1600 hours, local time). For the data from all 10 days, mean flight lengths are shown in Figure 2. Mean flight counts (per day) are shown in Figure 3. More detailed data from a representative day are displayed for illustration purposes in Figures 4 - 6. Flight count, aggregate control time, and the AAI are displayed for Friday, October 22, 1993. The AAI for all aircraft types combined is displayed in Figure 7.

The advantages of the AAI become apparent when different aircraft types consistently have different mean flight lengths, as was the case with the Seattle data (see Figure 2). An example is the comparison between two aircraft types, Commercial-Turboprops and GA-Piston, which showed similar hour-long flight counts between 1000 and 1200 hours throughout the ten days of data (see Figure 4). If flight count were considered alone as a measure of activity, the two aircraft types could be considered to require similar amounts of a controller's attention during that time period. However, the types had different mean flight

Figure 2. Mean Flight Length (10 days)

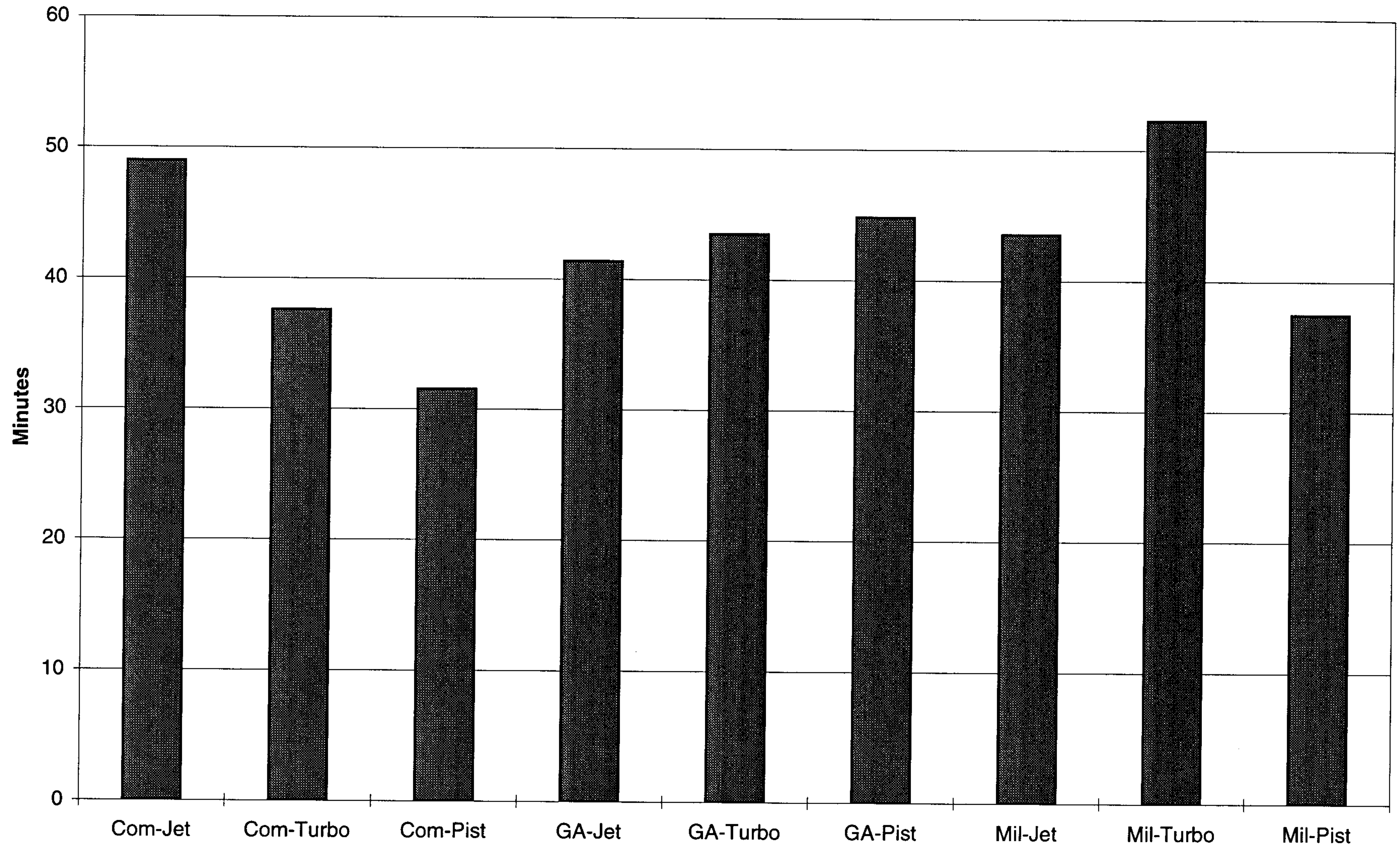


Figure 3. Mean Flight Count (10 days)

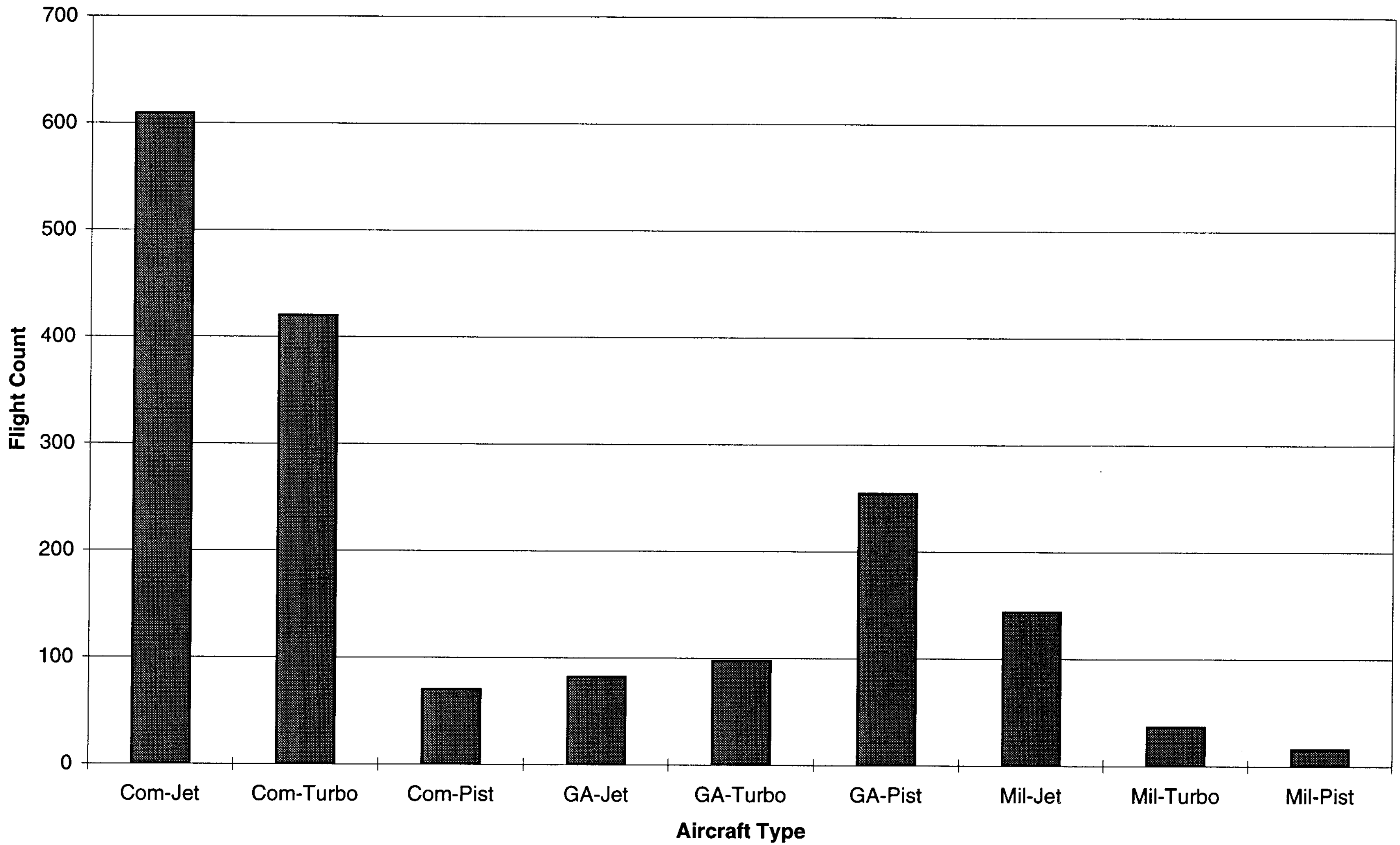


Figure 4. Flight Count - 10-22-93

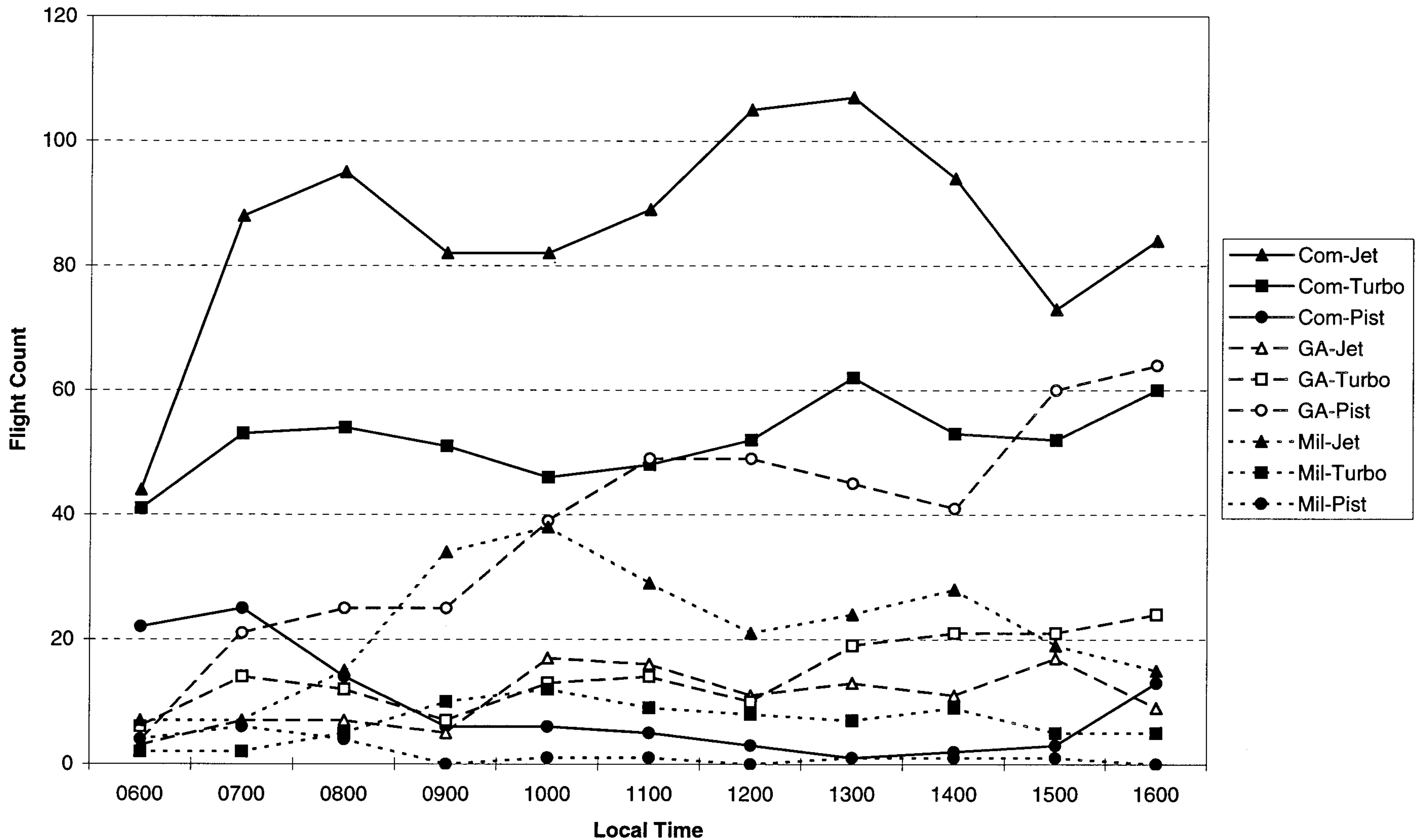


Figure 5. Aggregate Control Time - 10-22-93

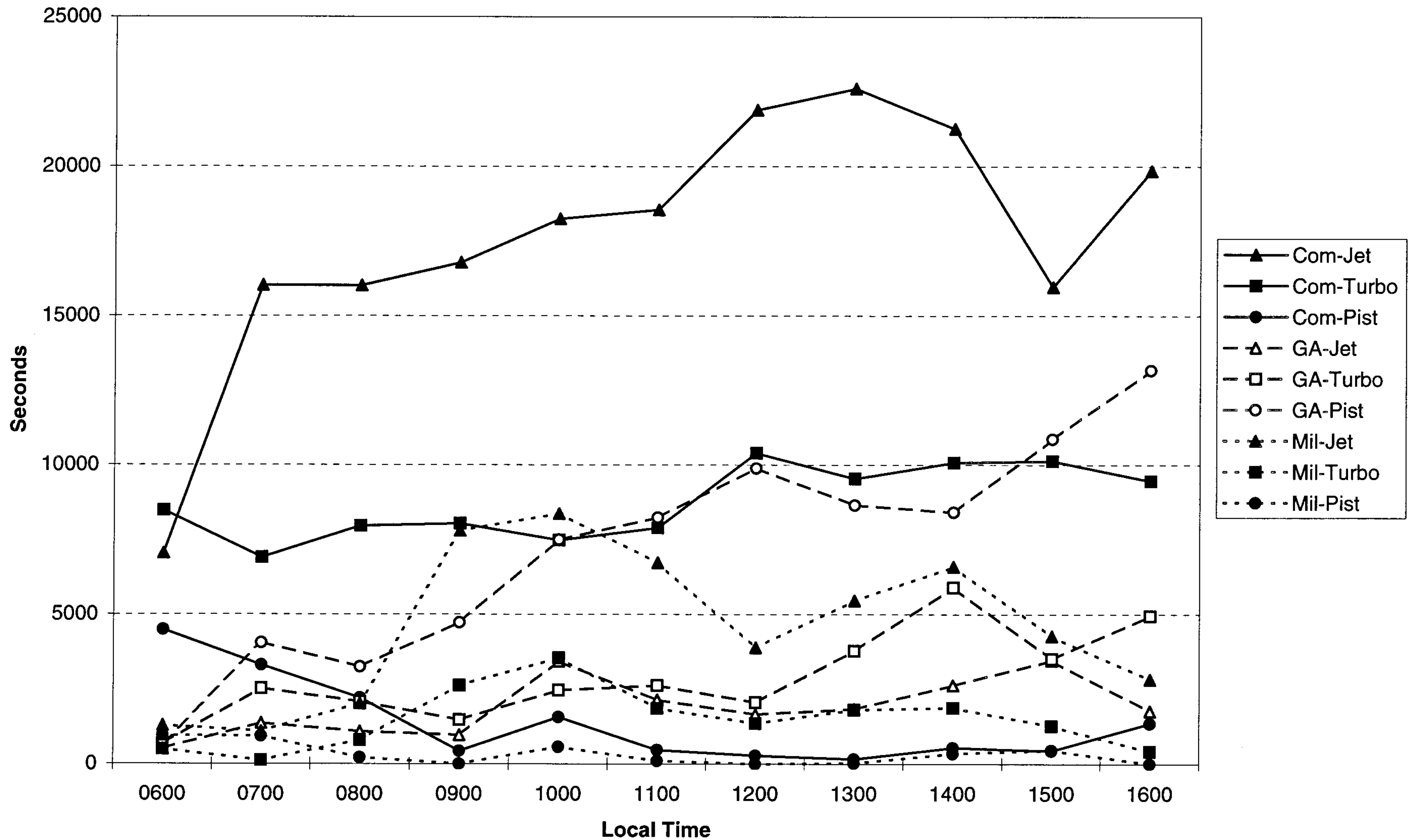


Figure 6. Aircraft Activity Index - 10-22-93

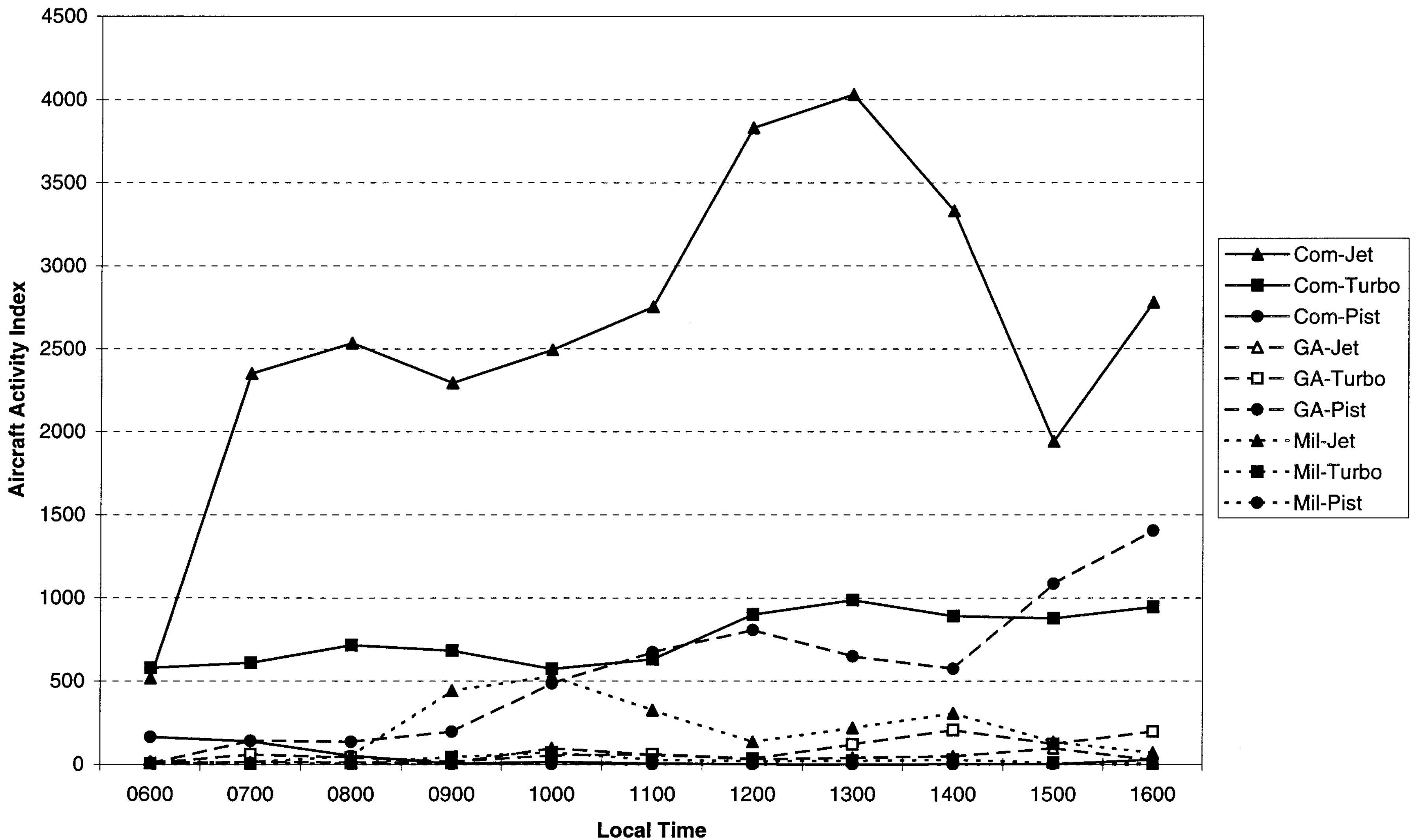
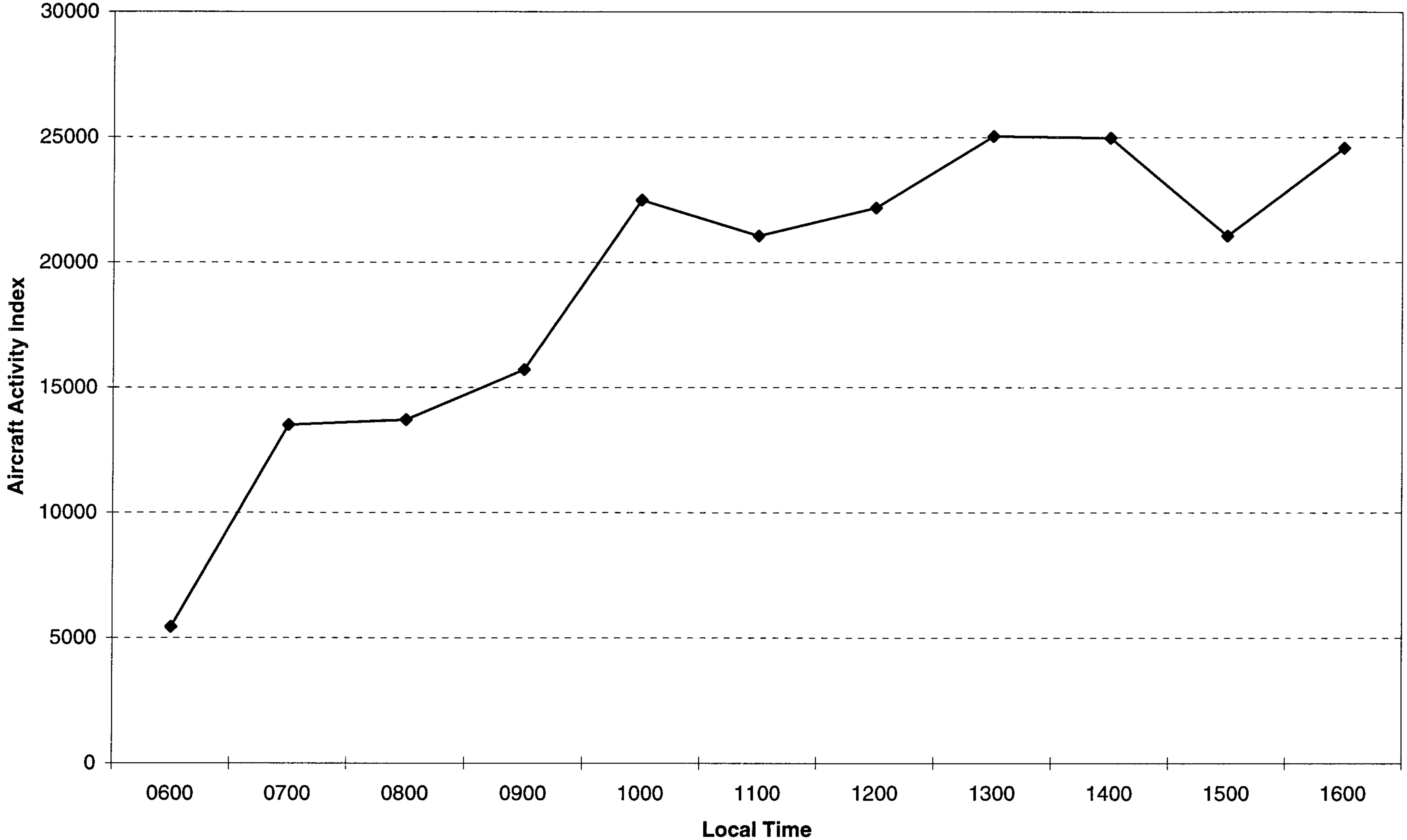


Figure 7. Aircraft Activity Index - All Aircraft Types - 10-22-93



lengths with GA-Piston flights (*M*=44.83, *SE*=0.59) being about 7 minutes longer than Commercial-Turboprop flights (*M*=37.58, *SE*=0.25), and possibly requiring more of the controller's attention. A more dramatic example is the comparison between Commercial-Piston flights and Military-Turboprop flights. These groups had similar hour-long flight counts throughout the data, but the average duration of the military flights (*M*=52.28, *SE*=2.46) was approximately 20 minutes longer than the commercial flights (*M*=31.52, *SE*=0.77).

DISCUSSION

Some of the disadvantages of using flight count and control time by themselves as activity measures are apparent in the Seattle data. Because Commercial-Piston flights were usually the shortest, the amount of attention required to control them may be over-represented in the flight count measure, as this measure is insensitive to flight lengths. Conversely, the controller attention associated with Commercial-Piston flights may be under-represented in the aggregate control time measure—more flights were controlled per unit of control time. Similarly, the controller attention required by Commercial-Jets, which usually had longer flight lengths, may be under-represented in the flight count measure and over-represented in the aggregate control time measure. The AAI is a more informative measure than either of the simpler measures alone because it is sensitive to both the number and length of flights.

The value of calculating separate index values for different aircraft types can be illustrated by comparing Figures 6 and 7. For example, the activity associated with hours 1200 and 1500 appears to be the same when aircraft types are combined (Figure 7). However, when aircraft types are considered separately as in Figure 6, the activity appears to be noticeably different, with more Commercial-Jet activity at 1200 than at 1500.

In the future, this index of activity can be used in conjunction with other ATC measures to establish baseline data for specific sectors or groups of sectors. This use will facilitate evaluation of new systems and procedures. As new technologies are applied to both ATC systems and to aircraft, resulting changes in airspace activity, including controller taskload, must be evaluated. Objective measures such as the AAI will contribute to such evaluations. Other measures that may reflect controller taskload are also being investigated, including aircraft activity (numbers and amounts of changes in heading, speed, and altitude), controller activities (numbers and types of keyboard entries), and sector characteristics. The refinement and development of these measures will enhance capabilities for evaluating ATC systems and effectively managing airspace.

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