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Civil Tiltrotor Feasibility Study for the New York and Washington Terminal Areas

Virginia Stouffer, Jesse Johnson, and Joana Gribko
Logistics Management Institute, McLean, Virginia

January 2001

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Chapter 1

Introduction and Summary

One of NASA's aeronautical research goals is to triple throughput in the national airspace system (NAS) in all weather conditions while maintaining safety. NASA has pursued a number of different potential solutions to address this challenge. LMI was tasked by NASA to estimate congestion and throughput benefits of an advanced Civil Tiltrotor (CTR) aircraft, to help NASA determine whether CTR research should continue to receive funding. The effort was not meant to be an exhaustive examination of the benefits of CTR production, but a quick study to measure whether or not CTRs would be a strong contributor to NASA's Three Pillars capacity goals. NASA's Three Pillars Program began in 1997 and is an on-going effort to improve to airspace capacity, with planned program assessments scheduled for 2007 and 2017.

The CTR program is still very developmental, so this analysis was based on proposed operating requirements, rather than on actual prototypes or mock-ups. Because of this generality, many assumptions had to be made. Also, this study was not intended to be a benefit study of CTRs.

The CTR is projected to improve congestion at passenger origin and destination points rather than the area in between, so a terminal area study was designed. To make the study more robust, more than one terminal site was studied. Modeling in some detail was required to show how the CTR would interact with existing traffic. Balancing a quick study against the need for detail, two terminal areas were selected for this analysis. Newark was selected to represent a large, busy airport, and Dulles was selected to represent a medium-sized airport with extensive turboprop traffic.

LMI analyzed CTR operations three ways: in a fast-time modeling simulation, to determine delay and throughput impacts; using a noise model, to determine local environment impact; and with an economic model, in order to determine the price viability of a CTR. The fast-time simulation and noise model examined potential CTR operations in a 1999 traffic and capacity environment, using 1999, 2007, and 2017 aircraft traffic levels. That is, three different travel demand levels were examined while holding airport capacity and technology levels constant. The economic model is only valid in a single time frame.

The fast-time simulation modeling exercise examined CTR operation in Visual Meteorological Conditions (VMC) and in Instrument Meteorological Conditions (IMC) category 2 at both terminal areas.[1] The results of all three analyses are summarized below.

FAST TIME SIMULATION RESULTS

The basic benefit premise behind fast time modeling was that CTR would be used instead of turboprop aircraft at congested airports, and the CTRs would land and depart on underutilized runways or helipads. Runway queues would be shortened and terminal airspace bottlenecks would be alleviated or mitigated. We did not assume that jet aircraft would be placed in the vacated turboprop slots.

In general, the greater manueverability of the CTR created a minimum of five to six percent improvement in total delays in a terminal area. Offloading traffic to a CTR-specific runway to reduce delays was successful to varying degrees; the results were sensitive to fleet mix and scheduling. Introducing CTRs to an airport will require optimization of the traffic mix, something not done in this quick overview. Too few aircraft were replaced by CTRs in Newark, and too many were replaced at Dulles. Newark showed delay reduction at all traffic levels, with greater improvement in IMC than VMC. Dulles had mixed results: in some cases reduced delays and increased delays in others. See Table 1-1 for a summary of results.

Table 1-1. Delay Reduction in CTR Fast-Time Simulations

	Traffic level		
Simulation	1999 (%)	2007 (%)	2017(%)
Newark weighted result	8.2	9.9	9.0
VMC	5.0	2.3	0.7
IMC	37.0	78.4	89.5
Dulles weighted result	4.2	101.3	-8.9
VMC	6.0	114.0	-9.5
IMC	-12.5	-13.2	-3.5

NOISE MODELING RESULTS

LMI used an FAA-certified Integrated Noise Model (INM) to model the impact of CTR noise on people and communities near the airports studied. Since the CTR is experimental, the noise data was scarce. Limited noise emission data from experimental models at low altitudes, provided by NASA Langley, was input to the INM. Thrust data was created based on operational requirements; approach and take-off path profiles were created based on small aircraft; high altitude and Dop-

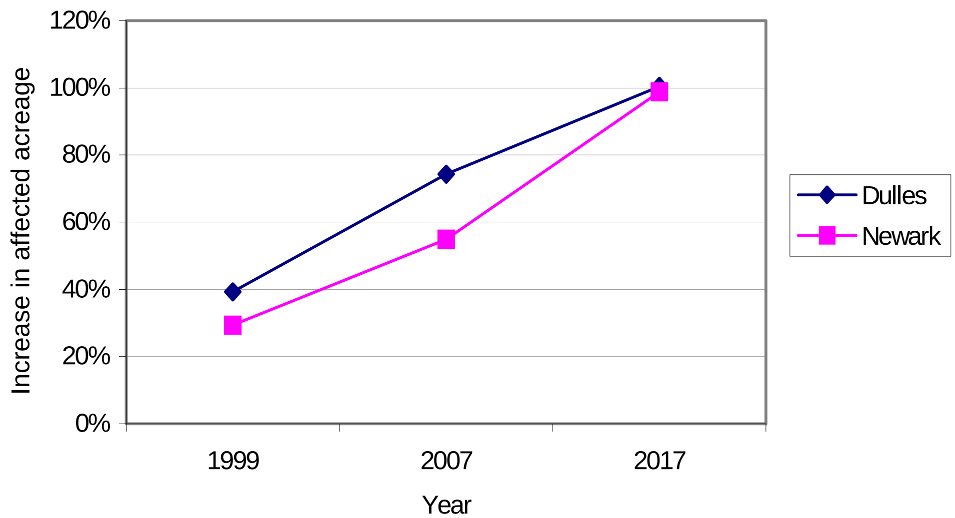
[1] IMC category 2 refers to a ceiling of 300 feet or less and visibility of a half-mile or less.

pler shift data were based on Sikorsky S-76 helicopters. The noise results should be viewed with caution, since much of the underlying data was assumed. We ran the model against 1999, 2007, and 2017 traffic levels, using existing datasets of population base for 1993, 2005, and 2015.

The noise impact of CTRs was substantial at Dulles in all time frames. The noise impact of CTRs at Newark was substantial only in the future and negative or negligible in the present. At Newark, fewer houses and less acreage was impacted at the 75 dB level at the 1999 traffic level; that is, noise levels actually decreased with CTRs in the fleet, as compared to today's traffic. (Noise levels increased or held constant in 1999 for lower dB levels.)

A reduced version of the noise results is depicted below, in Figure 1-1. Averaging the affected off-airport acreage across all noise levels shows how CTRs use increase noise levels. We cannot caution enough, however, that the noise model inputs were largely assumed from existing aircraft; in particular, the use of a Sikorsky helicopter's sound fade characteristics in large part drives these increased noise levels. Unfortunately, at the time of the study, no better data was available.

Figure 1–1. Increases In Noise Levels Due To CTR Operation



Economic Modeling Results

Using a nonrecurring industry investment level of 1.2 billion dollars, we computed that the minimum production run of 506 aircraft would result in a price tag of twenty million dollars (1999$) per CTR in the year 2010. If demand were four times greater, purchase price would fall to approximately $11.2 million per aircraft. The 506 aircraft production run would result in average operating costs slightly higher than turbojets and many turboprops. In our analysis, the $20 million-dollar CTRs would only operate in markets in which they could command a fare premium. Newark, with its congestion, is a good example of such a market.

Production of the CTR is projected to begin in 2010. The CTRs are designed to replace turboprop aircraft, which are owned predominantly by second tier airlines. Second-tier airlines, also called commuter airlines, are much less likely to be able to carry the payments associated with new aircraft, and tend to operate in markets that are only profitable using used aircraft. These carriers would ideally favor the purchase of used aircraft, but used CTR aircraft are unlikely to be available until 10 years after their initial introduction.

Chapter 2
Parameters

Study Parameters

LMI was tasked by NASA to assess the potential contribution of a developmental Civil Tiltrotor (CTR) to NASA's goal of tripling throughput in the national airspace system (NAS) in all weather conditions while maintaining safety. We used fast-time airspace modeling to analyze CTR operations with existing and future demand at two major U.S. airports, and at the same time analyzed the economic feasibility of introducing CTRs in the near future. We also performed noise modeling of baseline and with-CTR traffic flows for present and future flows.

The CTR is being proposed as a potential improvement to airspace capacity as part of NASA's Three Pillars Program. Assessments of NASA's improvements are planned for target years 2007 and 2017. Additionally, in making these assessments we were constrained to consider only NASA-funded improvements in airspace architecture.

CTR Parameters

The CTR aircraft envisioned by NASA does not yet exist. A number of studies preceded LMI's effort and provided some parameters on the needed attributes of an economically viable CTR. The guidance from these studies was as follows:

- Holds 40 passengers
- Range to 600 miles
- Top speed around 300 knots
- Service ceiling around 30,000 feet
- Tolerable interior noise
- Exterior noise about the same as a turboprop, exact noise data supplied (see Appendix B)
- Aircraft-like cruise
- Helicopter-like manueverability when rotors are rotated
- Three to six percent glideslope for landing

- 100-foot runway for take off and landing

Benefit Philosophy

We derived several potential usage scenarios for CTRs. They are:

- CTR as urban center commuter taxi;
- CTR as transport to locations with difficult ingress/egress paths;
- CTR as turboprop replacement for concrete-limited airports.

The first uses CTR in commuter rush hours, as high-tech air buses. A number of considerations come into play in this scenario:

- how to offer reliable service;
- how to offer economically viable frequency of service;
- competition with helicopters;
- IFR/VFR traffic rules.

For the CTR to be economically viable in this environment, it will have to offer service as reliable and convenient as commuter trains, buses, and cars; otherwise demand will lag, if customers are uncertain whether the CTR will run given the weather condition. To meet the reliability and availability of ground transport, CTRs may have to operate in Category II IMC. Helicopters currently provide VFR commuter service at a cost significantly lower than CTRs. Highest demand for transport is anticipated to come from the commuter rush-hours.

The CTR is more expensive than these ground modes of transportation, so it must offer something extra, such as speed. Helicopters already serve this market, particularly in New York, and for far less cost. Although helicopters do not operate under IMC, helicopters could be equipped with DGPS to do so. Under existing airspace rules, the CTR would have to fly VFR routes; close to the ground and at lower speeds; as helicopters currently do. The FAA may require instrument approaches to be established for new suburban IMC approaches and departures.

This usage scenario basically proposes CTRs as a substitute for commuter mass transit. While this may be a viable use, we believe it does not fall within the purview of “tripling airspace system capacity.” Also, helicopters already serve this need, and could be upgraded to compete with CTRs. CTRs may be used as commuter vehicles, which will contribute to the saleability of CTRs and thus lower the acquisition cost, but we did not feel this was the biggest benefit area for in-depth study and simulation.

The second addresses the use of the CTR in specific areas. Intra-Hawaii travel, travel in and out of mountain ski resorts, the Virgin Islands, and operations to resource-deprived airfields commonly found in other countries are several examples. It is likely CTRs could viably serve these markets, certainly as a charter operator and perhaps on a scheduled basis. However, there are only a dozen or so such locations in the United States that require the special maneuvering capabilities of the CTR. While the presence of these markets will encourage CTR sales and may in fact command the cost premium that could drive the CTR into production, these secondary markets were not seen as the biggest opportunity for tripling throughput in the airspace system.

The third benefit area seemed to have great potential for increasing the capacity of the airspace system without requiring new runways or expensive electronic equipment. CTRs could replace turboprop flights at any airport, but at concrete-limited airports CTRs have the capability to land on helipads and thus deliver passengers without congesting main runways. Based on this philosophy, we examined traffic records for airports out of the top 50 United States busiest by operations that were also in the top ten U.S. airports for commuter operations. We wanted to look at an extremely busy, congested airport and a "medium" traffic level airport, with achievable modeling challenges. We selected Dulles International and Newark. Then we began to assess how CTRs might fit into the economic environment of the Northeast.

Chapter 3
Airspace Study

Finding Airspace for CTRs

We had a philosophy of using CTRs at concrete-limited airports, but did not know exactly how it would be implemented, and how CTRs would blend with existing traffic patterns. Based on experience in airspace modeling, we assumed that CTRs would fly as existing aircraft through en route airspace; nothing in the CTR capabilities indicated a predilection for special routing, such as higher ceiling, faster speed, or better navigational accuracy. Any improvements CTRs could provide would come in the terminal airspaces. We visited the New York TRACON and the Potomac TRACON office, and spoke with controllers, supervisors, and other airspace modelers. Initially we hypothesized that CTRs could use a new flow path into airports, either with altitudinal or lateral offsets from existing traffic, and went out to seek those free airspaces. Neither offset can be accomplished in the busy terminal airspaces of the United States because the airspace laterally or altitudinally adjacent is already occupied with other aircraft. For instance, the southbound turboprops and jets arriving Newark at 5,000 and 6,000 feet cross LaGuardia departures at 7,000 and 8,000, while the airspace at 4,000 and below is owned by the IFR and VFR traffic in and out of Teterboro and Essex. Both Newark and Dulles' easternmost runways are only 3 nautical miles from the airspace boundary of the next major airport; LaGuardia and Reagan National, respectively. Given airspace separation requirements, this means no flows can be sent between the runway and the boundary inside the Newark and Dulles' side of the airspace. We also considered and rejected the idea of sending CTRs through helicopter and VFR corridors. The far greater speed and manueverability of the CTR would cause CTRs to dominate those airspaces, and make them less safe for general aviation aircraft. In sum, airports that are already congested do not tend to have free airspace for new traffic flows.

Use of "Stub" Runways

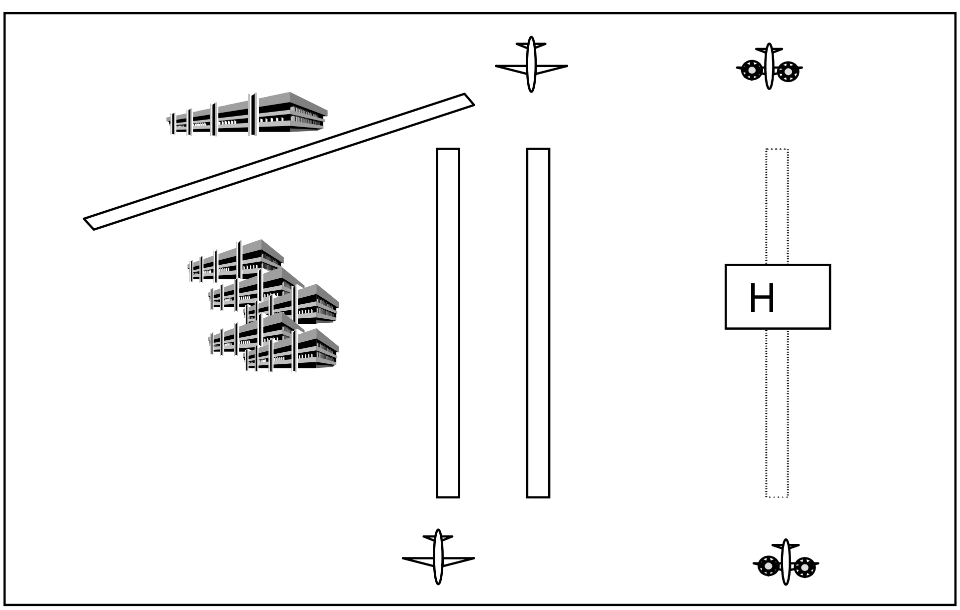
Other CTR studies had examined the possibility of sending CTRs to airports' "stub" runways; that is, runways less than 5,000 feet long that do not accommodate jet arrivals and departures, and that are often are closed when visibility drops. Examples of stubs are: at Newark, runway 11/29; and runway 30/12 at Dulles. These runways are underutilized and projected to become more underutilized as turboprop traffic decreases in the near future. CTRs could of course follow the existing turboprop flows into those stub runways. One notable and recent study proposed moving all turboprop traffic off Newark's 11/29 and using that runway exclusively for CTRs. This could be done. However, in a mixed traffic environment—one that that still has turboprops providing service—this pushes turboprops onto the main runway, creating more delays for jets. And turboprops are likely to remain in service for some years after 2010. Closing an entire runway to turboprops in favor of CTRs could perhaps be justified if more than one helipad could be established on the closed runway. Doing so would require relaxation of existing FAA rules on runway use, which has not been proposed. At Newark, all approaches to 11/29 would still have to come from the same direction and over existing routes due to noise restrictions, so even with the establishment of multiple helipads on 11/29 and significant changes to Federal Aviation Regulations, capacity increases would be constrained by airspace congestion.

We also faced the self-imposed restriction that we would not take airspace away from general aviation. Low-altitude routes were available in New York where helicopters ferried traffic into Manhattan via the rivers. CTRs would be unlikely to mix peaceably with VFR helicopter traffic due to the CTR's far greater speed.

Placing CTR Pads

Given that CTRs could not claim a new terminal airspace for themselves, that we did not want to take away the VFR airspace, and the considerable noise restrictions in congested terminal airspaces, very few options for improving throughput remained. Ultimately we decided to try to establish parallel, simultaneous and independent "runways" for CTRs, parallel to existing runways and approaches. CTRs would fly the same routes as turboprops in the en route and terminal airspace, but once reaching the final approach fix, would execute a wider turn and perform a simultaneous independent approach to a parallel CTR-only runway. Our subject airports have main parallel runways that handle the majority of traffic in all weather conditions, so the CTR runway/helipad would be one mile distant from the existing main runway pair. (See Figures 3-1 and 3-2).

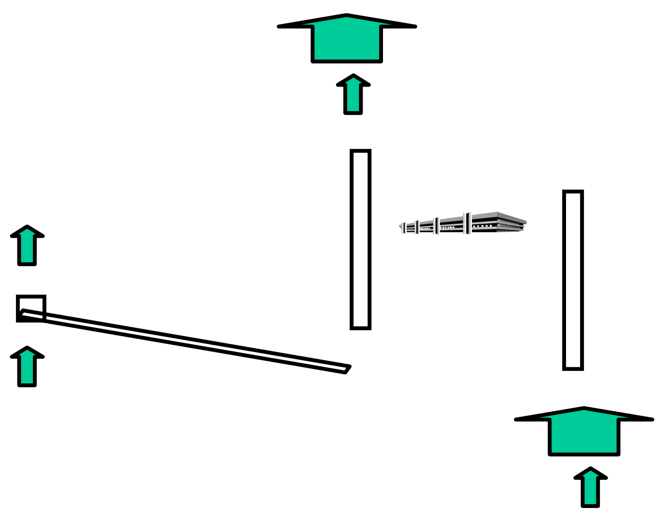
Figure 3–1. CTR Runway (New York)



We attempted to place CTR pads on existing concrete. The new CTR runway/helipad “03/22” for Newark would be established on a pier east of I-95, requiring some infrastructure to connect passengers in the CTR area to the main Newark terminal; but the pad can function in all weather conditions. Continental Airlines’ Newark representative was consulted about the proposed CTR pad, and judged that the proposal was justifiable if it enables sufficient delay reductions. The infrastructure obstacles to be overcome in this placement are regarded as less severe than the political obstacles posed by adding airspace paths (and thus aircraft noise) anywhere over northern New Jersey.

At Dulles, the solution was less obvious, since runway 12/30’s traffic pattern provides a conflict for any traffic west of the main runways, and both real estate and airspace are constrained on the east side of the main runways. Six-lane Highway 28 runs parallel to the main runway approximately one mile to the east, and the other side of Highway 28 is populated with large office buildings, including one complex that houses the FAA’s National Airspace Management Center, where all the nations’ air traffic problems are addressed in real time. There is considerable land available to the west; but without concrete or taxiways in that area. We considered placing the CTR pad within a five mile radius of the terminal and noted that Leesburg airport is approximately five miles from Dulles airport to the northwest; however, the taxi time in such a placement would likely be onerous. Ultimately the taxiway at the end of runway 12/30 became our CTR pad, over a mile west of the main parallel runways, though it can only be used when runway 12/30 is closed.

Figure 3–2. CTR Runway (Dulles)



Having identified our potential CTR improvements, we collected information to perform the airspace simulation, which is detailed in the next chapter.

Chapter 4

Airspace Simulation

MODEL SELECTION AND INPUTS

Our objective in using a fast-time airspace simulation model was to quickly determine whether and how CTRs would mix with other air traffic. To that end, we modeled airspace and other traffic in great detail, but made gross assumptions about how CTRs would enter service and their prevalence at our subject airports. Our mission was to discover whether CTRs could significantly aid in reducing congestion and increasing throughput. Our discoveries in this study will provide the groundwork for future studies which may refine our gross economic assumptions.

We used the Total Airspace and Airport Modeler (TAAM) simulation model, version 2.9.7., to discover how CTRs would operate in congested airspace, and how they would impact other traffic. TAAM is a premier airspace modeling tool that can simulate all domains, from gate and taxiway movements through takeoff, climbout, separation conflicts, and separation strategies. It is aircraft-characteristic based, making it ideal for evaluating new aircraft. Readers of this report who are TAAM users may find it useful to consult Appendix B, where a listing of the TAAM program files used in the eight 1999 simulations can be found.

In order to determine whether the new parallel CTR pads would actually be non-interfering with local traffic, and to completely measure CTRs impacts on delays and throughput, we modeled each terminal area in great detail, including actual air traffic control sector shapes, nearby airports, and all scheduled traffic flows through the area. Models were created to represent traffic flows in both Visual Meteorological Conditions (VMC) and Category 2 Instrument Meteorological Conditions (IMC), to ensure we captured a representative slice of the required "all weather conditions."

Programmed inputs included:

- Dulles simulation:
  - Dulles International (IAD), Reagan National (DCA), and Baltimore-Washington International (BWI) airports - runways only
  - Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARS) – the very latest (10/6/99) for IAD

- Configuration and runway usage files Official Airline Guide flight data
- IMC and VMC configurations

- Newark:
  - Newark International, John F. Kennedy International, LaGuardia International and Teterboro Airports - runways only
  - SIDs, STARS, usage files
  - Enhanced Traffic Measurement System flight data
  - IMC and VMC configurations

Because of our focus on terminal operations, we spent a great deal of time programming STARs and SIDs. STARs are the arrival path an aircraft takes through the terminal area, from up to 250 nautical miles away from its destination down to the runway touchdown. SIDs are the defined routes aircraft must follow when exiting a terminal area before entering the cruise portion of their flight. Most holding and maneuvering is made during the SID or STAR portion of the flight.

We were careful to preserve the separate routes used by jets, pistons, and turboprops. In our New York model, this meant separate arrival fixes for jets and for turboprops. At least one STAR and SID must be programmed for each runway to accept traffic from each arrival fix or feed traffic to each departure fix. Where there are three runways in use at an airport, we programmed three SIDs, one for each departure fix from that runway, and three STARs to route aircraft to the proper runway. If modeling more than one configuration (e.g., south operations and north operations), new sets of STARs and SIDs must be programmed for each configuration. Some time can be saved if a particular runway never accepts jets or never accepts turboprops. In this case, there is no need to program the instructions to bring that type of aircraft to and from the runway.

We mapped the endpoints of SIDs and STARs in use for each airport in each simulation. We sorted the route file for all flights to and from each airport and listed the endpoints of each route. A great deal of programming time was spent to ensure that endpoints of routes matched the endpoints of SIDs and STARs; otherwise TAAM sends aircraft on a “default” approach or departure. These “defaults” generally contravene a terminals’ standard operating procedures and would render our careful terminal modeling useless. In most cases we changed the route file, adding arrival fixes and departure gates; in some cases we found there were no defined STARs to bring in a little-used route. In those cases we composed STARs based on controllers’ flow diagrams, radar pictures, and the standard operating procedures. Most STARs and SIDs for an airport resemble trees, in that all the routes converge on a final pattern to or from a runway end, so there is very little guesswork involved in programming a new SID or STAR.

Separate STARs also had to be programmed for our IMC simulations, since operations in that visibility require a 12-mile final approach. Not all runways are open under IMC; IMC STARs and SIDs were not programmed for non-open runways.

In the New York simulation, all aircraft types used the same routes, (also called "jetways," or "juliets"), and jets and props were instructed to fly at different altitudes using the demand file. In the terminal environment, turbos generally fly 2,000 feet lower than jets on the same route. There are some exceptions—particularly slow or underpowered jets will sometimes be routed on the turboprop route, and very high performance turboprops can travel along jet routes if they prefer (when congestion is lighter on that route). For example, jets and turboprops arriving to Newark from New England must either pass over or under LaGuardia and JFK traffic; high performance aircraft generally go over, at 8,000 feet or above; lower-performance aircraft go under, at 4,000 feet. An aircraft's ability to execute steep arrival slopes determines which path it will be directed to. This performance capability is identified in TAAMs aircraft characteristic file.

In Washington, the Potomac group began a convention of creating separate routes for turboprops, jets, and pistons, distinguished by a ".J" (or ".P", or ".T") after the route name. For example, the route between Dulles and Orlando is generally called KIADKMCO; the Potomac group has created a new route file in which there are three routes for the same flight:

KIAD-KMCO.J

KIAD-KMCO.T

KIAD-KMCO.P

This naming convention enables modelers to make slight variations of routes based on group aircraft performance, such as the distance the aircraft is allowed to fly out over water; or how closely the aircraft must follow NAIADS as opposed to flying direct. Using Potomac's route file engendered a few changes in input programming for us; for instance, a route name must be assigned in the demand file by the programmer based on the aircraft type, which meant running a few lookup and write routines on all our demand files. Otherwise, TAAM would assign the first route it saw to all aircraft traveling that city-pair; in this case, the ".J", because it is first in the alphabet. We still had to define just as many STARs and SIDs.

In Washington, it tended to be the case that all aircraft used the same arrival and departure fix. In this case, the performance variables in the STAR and SID files were set to limit which aircraft opted for a particular SID or STAR. For instance, KIAD_01R_ROBRT_1.sta and KIAD_01R_ROBRT_2.sta are the STARs for jets and turbos, respectively, arriving to Dulles from the arrival fix Robert. In the first file, altitudes are set higher and the set of aircraft using the STAR is restricted to high performance jets and turbos; all other aircraft use the second, which has lower altitudes.

Because we had to program almost all our SIDs and STARs from scratch, we consolidated some arrival fixes; for example, all aircraft arriving to Kessel (ESL) always continue on to Armel (AML), so we eliminated Kessel as an arrival fix. We then searched the route file to write ESL AML KBWI on the ends of all routes that used to end as ESL KBWI.

AIRSPACE ROUTES

New York

We visited the New York TRACON to observe the New York area traffic flows, so that we would be able to replicate them as accurately as possible in the models. New York TRACON personnel allowed us to copy the Standard Operating Procedures Manual, the Memorandums of Agreement, and furnished traffic counts by runway for the past few months. TRACON personnel helped us graph the arrival and departure flows of Newark, Teterboro, LaGuardia, and JFK, working from airspace charts and a radar graphic. Reporting fixes and required altitudes were noted. These arrival and departure flows were then programmed into TAAM and were checked against reported arrival and departure rates.

Newark currently has two basic configurations, north/east and south/west, each running about half of the time in both IMC and VMC. Because gates and aprons are scarce, Newark always gives its departures priority; aircraft depart on the innermost runway (closest to terminal buildings), which is 22R in south operations and 04L in north operations. Incoming aircraft arrive on the outer runway and cross the inner runway to get to terminals and gates. Runway 11/29 is shorter, and is used for turboprop arrivals and departures. There is no airspace available to the east of runway 11/29, so turboprop aircraft either arrive on runway 11 or depart on runway 29, depending on whether an arrival push or departure push is occurring. LaGuardia and JFK own the airspace 3 nautical miles east of the 04R/22L runway centerline. In low visibility, runway 11/29 is closed and Newark only operates its 04/22 pair. The 04R-04L/22R-22L runways are 800 feet apart; even with PRM these runways cannot support simultaneous operations. We chose to model the south configuration: arrivals on 22R and departures on 22L.

LaGuardia has two runways perpendicular to each other, and typically dedicates one runway to arrivals and one runway to departures. Winds and weather conditions tend to run the same at LaGuardia as at Newark, so LaGuardia's operation basically mirrors Newark. When Newark is in a northeast configuration, so is LaGuardia. When Newark is southwest, so is LaGuardia. Since we selected the south (i.e., southwest) configuration for Newark, LaGuardia would normally also be in a southwest configuration, with arrivals on runway 22 and departures on runway 13. (See Figure 4-1 for illustration.) Most of the time, LaGuardia's IMC configuration is the same as its VMC configuration.

Figure 4-1 New York Airspace Flows in VMC

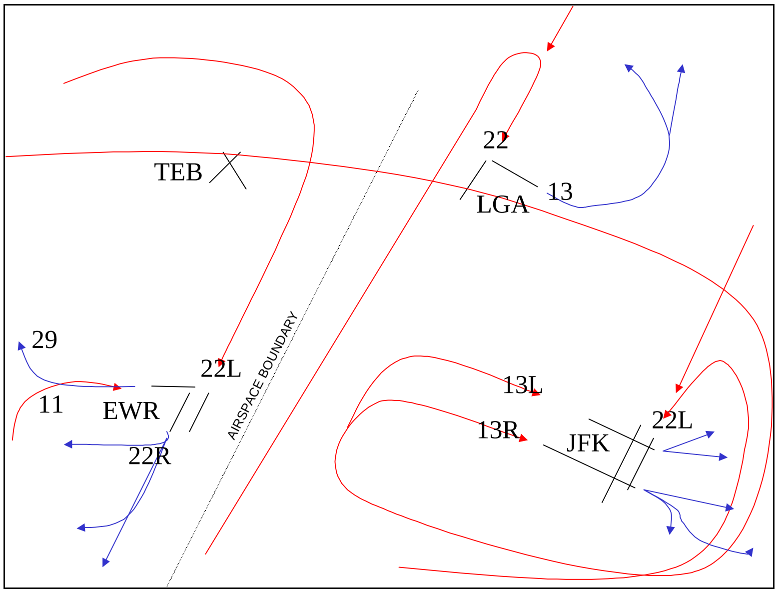


Figure is not to scale.

JFK operates runways independently of LaGuardia and Newark except when visibility drops very low. (In that case JFK goes to a single runway operation on 13R. The long final approach on 13R causes LaGuardia to close runway 22, putting both arrivals and departures on runway 13. The long final approach to LaGuardia's runway 13 causes Teterboro airport to shut down. Newark is not directly affected by this phenomenon.)

JFK has two sets of parallel runways. It could run either the 04/22 runway pair or the 13/31 runway pair, but it is hard to run both simultaneously because of the crossing configuration. The 13/31 parallel runways are chosen 75 percent of the time, for a variety of reasons, including that they are far enough apart to run simultaneous operations even in IMC. When using 13/31, arrivals land on 13L/31R (eastern runway) and departures take off on 13R/31L (the longest runway). JFK receives overseas flights in the late morning and flights originating from the west coast in the early afternoon, and departs overseas flights in a big push around 6 PM. Occasionally unusual upper winds cause all the arrivals show up at the same time, in mid-day. Because of its proximity to the ocean, the wind always shifts at JFK in the middle of the day. JFK shares some resources (radiobeacons) with other airports and has to schedule its usage. As a result, JFK sets a runway schedule every morning that has one configuration (either NW or SW) in the morning, and then SE or NW in the evening, after the ocean wind shift. Whether the airport operates south in the morning or in the evening tends to vary with summer and winter seasons. We chose the south configuration for our VMC model: arrive

13L, depart 13R, overflow arrivals on 22L, overflow departures on 22R. For simplicity, we programmed but did not run the change in wind pattern that occurs in the middle of the day. We found it sufficient proof to be able to model non-interfering approaches and departures without having to do the extra programming to make the model switch directions in the middle of the day. In IMC, only the two parallel 22 runways are used, as depicted in Figure 4-2.

Figure 4-2 New York Airspace Flows in IMC

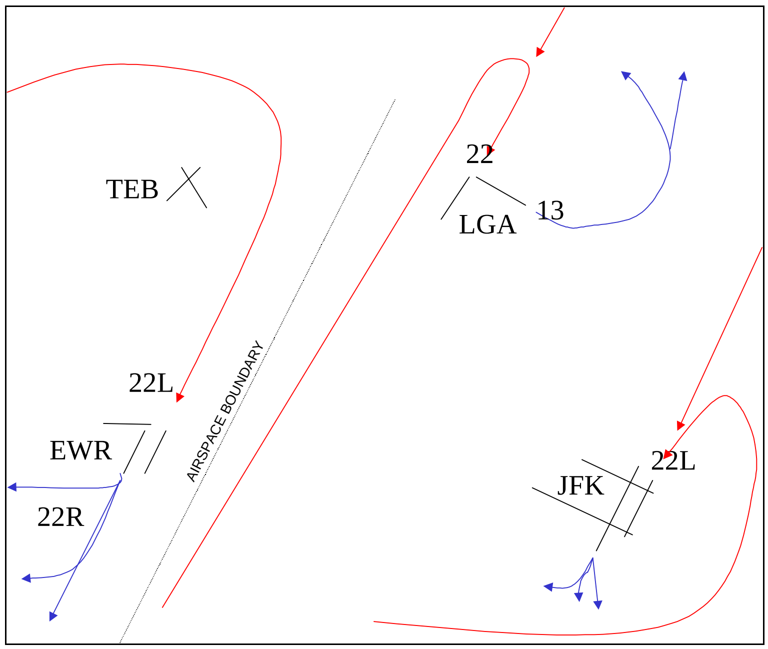


Figure is not to scale.

As stated in Chapter 3, it was difficult to place CTRs in the flows because the airspace around congested airports is in use. A two to three mile margin of error is used for lateral spacing, and thousand-foot increments altitudinally. Newark is only 15 miles from LaGuardia's center and about 20 miles from JFK's Very High Frequency OmniDirectional Range beacon(VOR); JFK and LaGuardia are only about 10 miles apart. The average runway is two miles long. So although the arrows in the diagrams above may appear to have spaces in between, there is actually very little airspace available. Teterboro, general aviation, go-around space and helicopter flows were not shown, to avoid confusion in the figures.

New York TRACON personnel made many suggestions for CTR flows and placements, but ultimately we decided the CTRs had to execute simultaneous independent parallel approaches to the main runways and not displace any existing traffic in order to be economically viable. We opted to place a CTR pad on one of the unused piers east of Newark, east of the New Jersey turnpike. A CTR terminal could be built there on existing concrete and buses or light rail could be used to shuttle passengers between the CTR terminal and main terminal. A light rail line is planned to connect Newark with Manhattan; the CTR terminal could be a second stop on that line. Part of our placement deliberations included discussions with a Continental airlines representative, and the pier placement was not ruled out or regarded as impossible. In terms of airspace, the CTR would approach Newark as if it were a jet aircraft, headed toward the main runways, and split off from the jet flow at the final approach fix for a simultaneous parallel approach. The piers are one mile east of the 04R/22L centerline, which enables independent approaches, but does not cross the LaGuardia/JFK airspace boundary. We assumed the CTR would be able to execute a different go-around flight profile than traditional jets and turboprops such that there would be no interference with the general aviation traffic to the east of the CTRs. This pier-side runway should work whether Newark is in a north or south configuration. We named the new runway 05/23. See Figure 4-3 for New York flows in VMC. In VMC, CTRs can land on 05/23 and on the turboprop runway (11/29), though turboprops cannot land on 05/23, as it is only 300 feet long.

Figure 4-3 New York Airspace Flows with CTRs in VMC

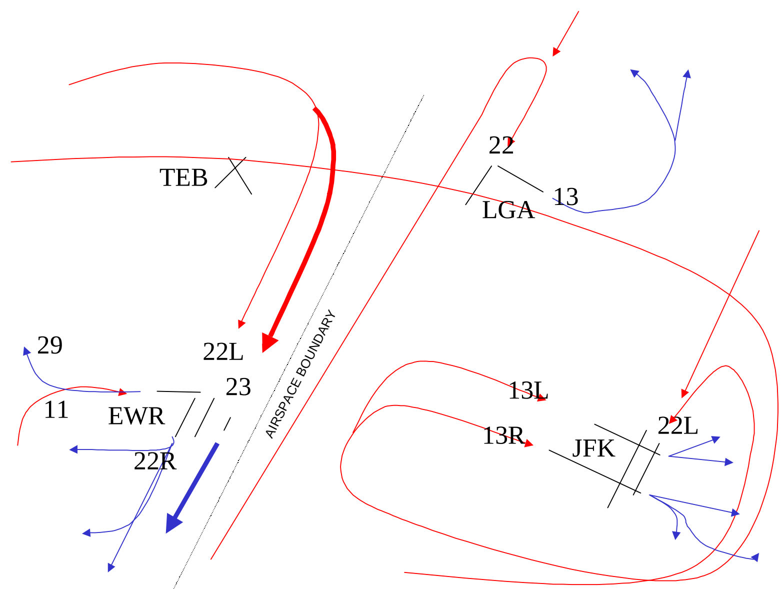


Figure not to scale

Figure 4-4 shows New York flows with CTRs in IMC. CTRs can operate to 05/23 in IMC, while the turboprop runway 11/29 is closed. Today, in practice, turboprops in IMC are routed to the main runways, if they can get off the ground. But because turboprops are often coming from closer destinations, when visibility drops at Newark, turboprops are often held on the ground at their origin airports. In a day when visibility is low throughout the day, turboprop flights may never leave the ground and can be cancelled.[1]

[1] In our simulation, flights over two hours late to depart are cancelled. We did not find any decrease in overall cancellations in the CTR simulation over existing traffic.

Figure 4-4 New York Airspace Flows With CTR in IMC

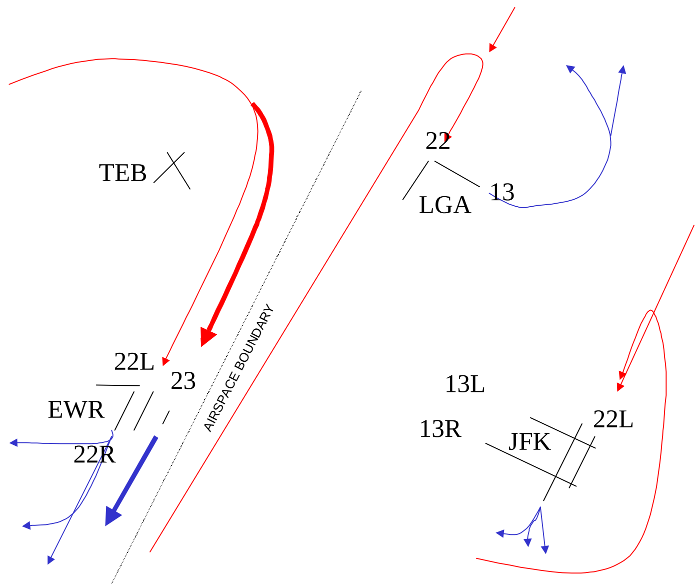


Figure not to scale.

Washington

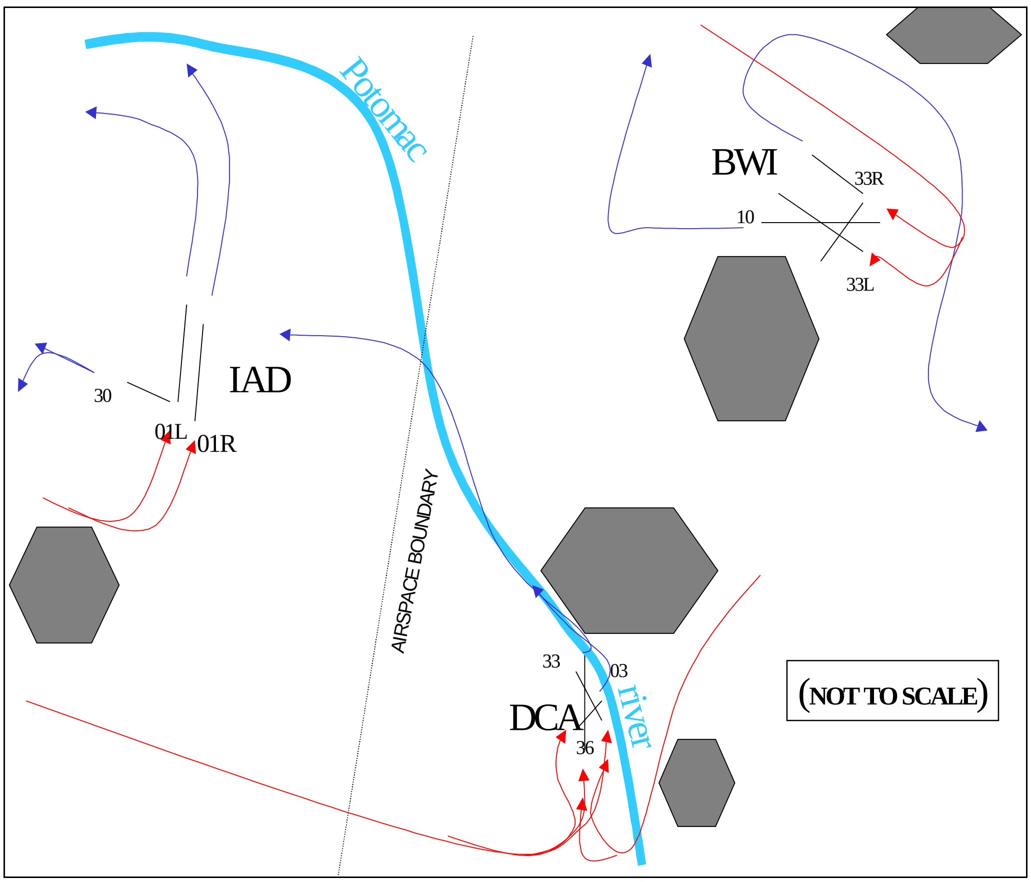
We are indebted to the Federal Aviation Administration's Potomac Metropolitan Control Facility Planning Office for sharing Washington/Dulles TAAM program files. The Potomac office provided configuration advice, traffic counts, electronic airport runway layout files, some electronic SIDs and STARs, and instructions for executing the remaining SIDs and STARs.

Dulles operates in two basic configurations: south or north; and it runs north about 75 percent of the time. Like Newark, Dulles has two main parallel runways (01/19) that handle the majority of the traffic. In VMC, Dulles staggers jet departures and arrivals, with arrivals on one parallel runway and departures on the other. Turboprops arrive or depart on the overflow runway (12/30) and on one of the parallels, depending on whether there is an arrival or departure push; also, runway assignment varies with destination. Dulles is busy with alternating arrival and departure pushes all day; there are six arrival pushes and six departure pushes between eight AM and ten PM. For our study, we picked the north configuration, which in VMC means jet arrivals on 01R, jet departures on 01L, turboprop arrivals on 01L, and turboprop departures on 30.

In IMC, the shorter runway, 12/30, is closed and all jets and props arrive on 01R/19R and depart on 01L/19L. Stub runways, presented at an angle to main runways, are generally closed in IMC because the approach controllers in the tower are unable to see well in reduced visibility. In IMC, if an aircraft had to execute a missed approach, the controllers would be unable to provide separation for the aircraft going around. Missed approaches are far more likely in IMC because pilots are prohibited from landing unless they can see the entire runway at their decision height.

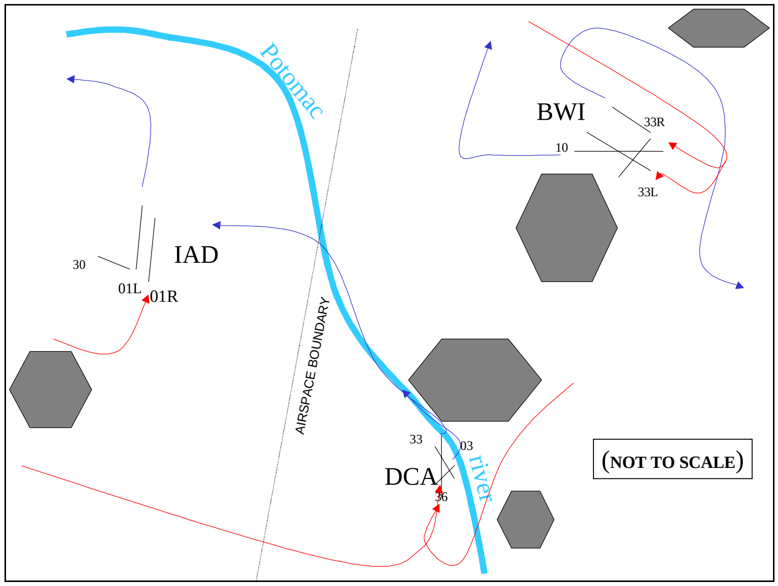
Reagan National airport operates either north or south, and experiences the same winds as Dulles. In VMC, National takes arrivals on its main runway, 18/36, and on one or two crossing runways: 03 and 33 or 21, depending on winds. In the north configuration, jets and props are landing on 36, and props are landing on 33 and 03. Jets depart 36, and turbos depart on 03. See Figure 4-5 for an illustration. The shaded hexagons in the figure represent special use airspace that is not open to commercial aircraft.

Figure 4-5 Washington Airspace Flows in VMC



In IMC, National goes from three arrival runways to two, but otherwise remains the same (see Figure 4-6.)

Figure 4-6 Washington Airspace Flows in IMC

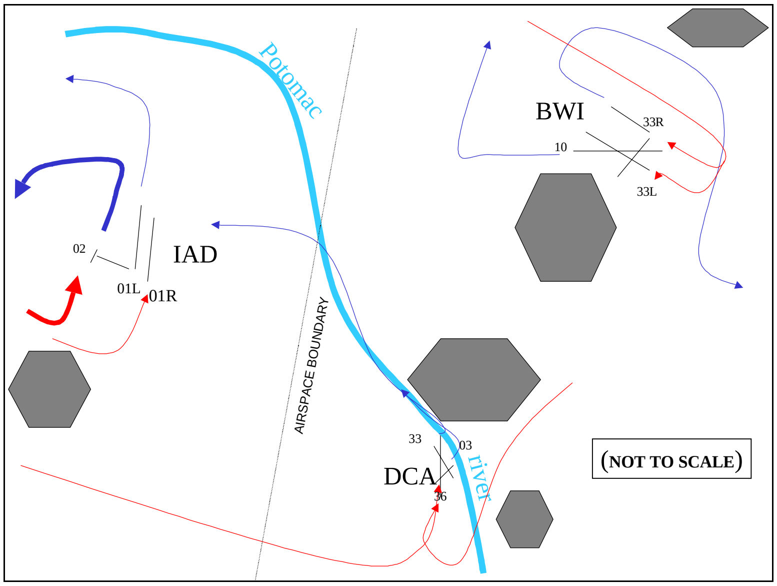


Baltimore-Washington International airport operates in East or West configuration, but predominantly West. As we debugged the Washington area model, we discovered that Baltimore operates mostly independently of Dulles and Reagan National. We continued to keep Baltimore in the model anyway; which turned out to be a wise decision, as delays in Baltimore showed a reduction in the CTR case that we did not expect.

Baltimore under its West VMC configuration, uses its main runways (15R/33L and 15L/33R) for jet arrivals, prop arrivals, and prop departures. The longest runway, 10/28, which crosses 33L/15R, is used for jet departures only. Runway 22/04, which at 6005 feet qualifies as a “stub” runway, is seldom used, though all four runways are equipped with ILS. Baltimore operates the same configuration in IMC as VMC.

Through meeting and discussion, the Potomac office personnel assisted us in modeling air routes as close to reality as possible. Potomac personnel also assisted in planning the placement of the CTR pads; but the decision was ultimately ours and any faults in judgment are our own. Placing CTRs at Dulles was much harder than at Newark. Dulles has fewer airspace conflicts with other airports, but more conflicts with its own airspace, since its own flows are spread out in many directions. Like Newark, Dulles’ easternmost runway’s airspace abuts airspace owned and used by Reagan National airport. There is room for an arrival flow but not sequencing along the eastern side of the airport; that corridor is used during north operations. In terms of land use, the area west and south of Dulles is airport owned and undeveloped; there is a great deal of room for expansion, though the terminal is on the northeast end of the airport, which would make for a long taxi. To the east of the airport is a six-lane highway, and office space on the other side of the highway, including FAA’s national traffic management office, formerly known as the Central Flow Control Facility. To the north there is greenspace and then residential area. Leesburg airport, with a single runway, is located seven miles to the northwest. In short, there is not much unused concrete in the five miles surrounding Dulles. Ultimately we decided to increase the use of the stub runway. In VMC, CTRs will mix with turboprops to use the stub runway; in IMC, when 12/30 is closed, CTRs will use the large apron and taxiway on the northeast end of 12/30 as a CTR/helipad. We called this new runway 02/19, and it is far enough from the 01/19 parallels to allow simultaneous parallel independent approaches. See Figure 4-7 for an illustration.

Figure 4-7 Washington Airspace Flows with CTR, in IMC



Current plans are for airspace changes to be made only every five years. Both Washington and New York recently completed airspace re-design studies. The configurations depicted should be accurate for about the next five years.

Modeling Future Years 2007 and 2017

Because NASA is also interested in alleviating congestion in the future, part of our study involved projecting traffic levels in NASA goalpost years 2007 and 2017, and modeling CTR interaction in those future years. Modeling so far into the future usually involves a lot of assumptions; for one thing, one-third of the current aircraft fleet retires approximately every ten years. Old aircraft types (such as Boeing 747s) are retired completely and new aircraft are introduced. The FAA and NASA both have a number of technologies under development now that are projected to alleviate congestion in the future. To simplify our task, we merely

assumed traffic levels would increase, and held all other factors constant, including fleet mix, aircraft types, and air traffic control separation levels. None of the FAA delay-reducing technologies under development were included, and the

NASA technologies under development were judged not relevant to this simulation. Traffic files were generated by LMI's LMINET and Air Carrier Investment Model (ACIM.) Using the FAA's current Terminal Area Forecast, LMINET compares traffic demand to runway and taxiway configurations and projects delay levels at each airport. ACIM translates the delay levels into decreased demand through fare hikes, delays, and cancellations. The end result is a traffic schedule that reflects both supply and demand. Schedules were also normalized to reflect a 50^{th} percentile traffic day for each year in the air traffic system, so that the results would apply to average traffic as much as possible. The detailed description of how we generated our traffic (demand) files for simulation follows.

Creating Demand Files

Using an existing Official Airline Guide schedule for January, 1997, we annualized the schedule so that it would reflect one-365th of traffic for 1997. We excerpted two sets of flights, one with origin/destination traffic from Newark, JFK, and LaGuardia; the other with origin/destination traffic from Dulles, Reagan National and Baltimore. Overall demand growth from 1997 to 1999 was 3.0 percent;[2] which allowed us to calculate the overall number of flights in 1999.[3] The rates of growth in traffic between specific city-pairs (e.g., flights between Dulles and Cleveland) from 1997 to 1999 were extracted from LMI's Air Carrier Operations Model and the Air Carrier Investment Model (ACIM), using the fratar algorithm.[4] We then added the appropriate number of flights for each city-pair to the 1997 schedule. At this point the new baseline 1999 schedule was complete.

In order to generate the 2007 and 2017 schedules for the TAAM models, we continued with the following process. LMI's Air Carrier Operations Model and the Air Carrier Investment Model provide schedules for the 64 LMINET airports[5] and their four-thousand–plus city pairs for various years. We isolated the number of flights between these airport pairs, in 1997, 2007, and 2017. We calculated the rates of growth to 2007 and 2017 for each airport pair.

We wrote a Pascal schedule generator program to merge the growth with the 1999 schedule. The program does three tasks: it converts all non-LMINET airports to OTR; it adds the growth to the schedule using a spatially uniform

[2] FAA Aviation Forecast '98- '09, tables I-4 and I-17

[3] Modeling and simulation were performed in summer 1999, when traffic levels for 1999 were still unavailable.

[4] Dou Long, Earl Wingrove, David Lee, Joana Gribko, Robert Hemm, and Peter Kostiuk. "*A Method for Evaluating Air Carrier Operational Strategies and Forecasting Air Traffic with Flight Delay*," LMI report NS902S1, October 1999.

[5] Any origin or destination airport that is not one of the 64 LMINET airports is replaced with the notation "OTR."

distribution; and it prints out the new flight schedules.[6] We designated added traffic by using “LM” or “LMI” in the flight’s callsign.

There is inherent error in this process due to rounding error; for example, if a city-pair’s growth rate between 1997 and 2007 is 1.2, then obviously we only added one flight, and the 0.2 is rounding error. There is currently a 3-14 flight difference between the flights expected by rate of growth and the added schedule flights (out of 400-800 flights). Also, general aviation aircraft were not included in the schedules.

Table 4-1. Traffic Levels

Simulation	Number of flights in simulation	Increase in traffic from previous simulation (%)
Washington—1999	2535	
Washington—2007	3097	20.0
Washington—2017	3515	12.6
New York—1999	3217	
New York—2007	3615	11.7
New York—2017	4032	10.9

ADDING CTRS

Flight Demand

One further wrinkle for generating flight (demand) files remained: our economic analysis projected that CTRs would not be available to enter widespread use until after 2010. Our compromise solution was to model 1999, 2007, and 2017 scenarios with and without CTRs. (It was important to model 1999 to calibrate the model with existing delay levels.) We were not able to use our economic model to predict how CTRs would replace existing aircraft, so we made some arbitrary assumptions. In 1999 and 2007, fifty percent of turboprop flights originating or destined for our subject airports and not deadheading would be replaced with CTRs; and in 2017, one hundred percent of turboprops at our subject airports would be replaced.

Although in our simulations we modeled entire terminal areas, to include the paths and airspaces of adjoining airports, when replacing turboprops we only replaced those going to or from our subject airport. So when we modeled Newark, we also modeled John F. Kennedy International and LaGuardia airports and flight paths, but only turboprops originating or destined for Newark were replaced with CTR traffic. The same was true for Dulles, using Baltimore and Reagan National.

[6] The year, the growth file, and the schedule file are designated in the command line and read by the program. The output includes both the schedule and a diagnostic file.

To illustrate, our 1999 traffic file for the New York area contained 3217 flights, of which 1265 were Newark's. Of those 1265, 146 were turboprops, and 73 were replaced with CTRs. All other flights to JFK and LaGuardia were unchanged. See Table 4-2 for the Washington/Dulles traffic mix and Table 4-3 for New York/Newark's mix. We followed this turboprop/CTR replacement scheme within a larger model to explore whether one airport could find advantage in CTRs vertical take off and landing capabilities by shunting a percentage of its traffic to another "runway." The CTRs were assumed to be operated as turboprops on the other end of their market pair: i.e., a Newark –to-Boston flight changed to CTR was assumed to land on regular runways at Boston. Future studies could explore what might happen if a several concrete-limited airports were to initiate CTR service with CTR runways.

Table 4-2. Traffic Mix for Dulles/Washington

Year simulated	Number of flights at Dulles, National, and Baltimore	Flights at Dulles only	Number of turboprop flights at Dulles	Number CTR flights at Dulles	Percentage of traffic at Dulles that is turboprop/CTR (%)
1999	2535	806	406	203	50.4
2007	3097	1080	574	212	53.1
2017	3515	1258	687	687	54.6

Note: figures are for one traffic day.

Table 4-3. Traffic Mix for Newark / New York

Year simulated	Number of flights at Newark, LaGuardia, and JFK	Flights at Newark only	Number of turboprop flights at Newark	Number CTR flights at Newark	Percentage of traffic at Newark that is turboprop/CTR (%)
1999	3217	1265	146	73	11.5
2007	3615	1501	283	145	18.9
2017	4032	1760	333	333	18.9

Note: figures are for one traffic day.

We replaced turboprop flights with one CTR flight each. Our economic research showed that although turboprops had an average number of 80 seats, their average load factor was below 50 percent and so effectively the demand could be fulfilled by a CTR. We realize that there may be markets in which a single CTR replacement flight will be inadequate for the demand; but modeling to that level of detail remains for another study.

Assumptions

In addition to the caveats listed above, in modeling this substitution of CTRs for turboprops, we made a number of assumptions:

- CTRs assumed CAT II landing capable with DGPS
- Airports with a CTR pad will create another arrival controller position for that traffic
- CTRs will not require the special equipment of FMS-nav, ADS-B or PRM to perform the modeled parallel simultaneous approaches
- If FMS-nav, ADS-B, or PRM were available in the future, further decreases in congestion may well be achievable in conjunction with CTR use.

Programming SIDs and STARs

Where CTRs acted like turboprops and used existing runways, there was no need for any programming change, in routes, SIDs, STARs, or the flight file. Where we created a new runway for CTRs, however, we created a whole new set of SIDs and STARs to connect the new runway to existing arrival and departure fixes. Additionally, we wrote a runway use rule for CTRs to “do use” their respective helipad runways. The “do use” command is a suggestion in TAAM; it is not the absolute proscription that “do not use” is. Under “do use,” aircraft will use the suggestion as long as delays do not reach an established threshold.

SIMULATION RESULTS

Surprisingly, all airports with any CTR origin or destination traffic (O/D), not just our subject airports, experienced some reduction in delays due to CTRs superior maneuverability. CTRs have a tighter turning radius and so are able to enter and exit holding stacks and turns “on a dime,” facilitating flow management for air traffic controllers. As a result of this improved maneuverability, all traffic in the Dulles and Newark 1999 plus-CTR simulations experienced 6 percent and 5 percent reduction in delays in VFR respectively. This was surprising at Dulles, since Dulles in its VFR CTR configuration does not have any additional landing capability. A few of the CTR flights at Dulles had origins and destinations at BWI, and BWI experienced a decrease in local airspace delays with CTRs. In IMC, Dulles experienced an unexpected increase in airspace delays; unexpected because Dulles has essentially another runway under CTR-IMC. Upon inspection, it was discovered that our arbitrary one-for-one replacement rule and random 50 percent replacement had preserved the airlines’ and commuters’ hubbing schedules; and so the CTRs were all arriving at the same time to use the CTR runway. In New York, CTR improvement was small, because turboprops make up a small percentage of traffic, and diverting 50 percent of turboprop traffic to an "extra" runway was not enough to alleviate New York traffic congestion. (While CTRs replaced 203 flights out of 806 at Dulles, CTRs only replaced 73 out of 1265 at Newark.)

Results from Dulles for 2007 and 2017 were puzzling and mixed. At times CTRs led to large reductions in delays; other times, small increases in delays. These results are probably due to schedule and fleet mix effects; i.e., having all the CTRs arriving at the same time in the arrival bank instead of spreading them out. In general, traffic delays in 2007 showed great improvement from the use of CTR in VFR, no improvement in IMC, and slightly worse performance in 2017 in both weather conditions. Overall we consider the results ambiguous. We conclude that greater work in scheduling CTRs would improve congestion at Dulles in the future.

Results from New York were not ambiguous, and showed reduction in delays from the use of CTRs. In New York in 1999, CTRs reduced delays in VFR by 5 percent and in IMC by 37 percent, for a projected weighted decrease of 8.2 percent. In 2007, use of CTRs decreased delays in VFR by 2.3 percent and in IMC by 78.4 percent, for a projected weighted decrease of 9.9 percent. In 2017, CTR use left total delay levels in VFR unchanged, and decreased delays in IMC by 89.5 percent, for a weighted decrease of 9 percent. A summary of the results is depicted in Table 4-4.

Table 4-4. Percent Improvement in Delays with CTRs (Negative Numbers Indicate Worsening)

	New York		Washington	
	VFR (%)	IMC (%)	VFR (%)	IMC (%)
1999	5.0	37.0	6.0	-12.5
2007	2.3	78.4	114.0	-13.2
2017	0.7	89.5	-9.5	-3.5

OPERATIONAL FINDINGS

Observing the simulation showed us some unexpected operational findings. Overall we were surprised by the simulation results. The negative trend in 2017 in both airport areas in VFR indicates congestion at the CTR landing pad, and schedule optimization should be added in future studies. The 50 percent replacement scheme of CTRs for turbos was clearly too few aircraft at Newark and too many aircraft at Dulles, indicating there is some optimal mix of jets, turboprops and CTRs for maximal throughput at each airport. Our general conclusion was that CTR reduces delays at congested terminals by 5 percent in any weather condition due to maneuverability; and reduced delays at Newark at the 10 percent level now and in the future, with ambiguous results at Dulles. We do not recommend extrapolation to a national level based on these results; more study is needed.

Chapter 5
Noise Impacts

MODELING INPUTS

LMI used an FAA-certified Integrated Noise Model (INM) to model the impact of CTR noise on people and communities near the airports studied. Noise level and thrust data for the new aircraft are entered into the INM, as depicted in Tables 5-1, 5-2, and 5-3. Noise emissions of current experimental models of the CTR at low altitudes were provided by NASA Langley (see References 1 and 2.)[1]

Since the CTR is experimental, the NASA noise data was limited to CTR performance to 500 feet. Other data and settings had to be created. Thrust settings were derived from the CTR performance profile created for the TAAM airspace model, which was in turn based on operational requirements. (The TAAM performance profile is reproduced in Appendix A.) Approach and take-off profiles beyond 500 feet were created based on small airplane capabilities; the noise characteristics associated with those coordinates was borrowed from the Sikorsky S-76 helicopter. Noise fade, or Doppler effect, was also borrowed from the Sikorsky S-76.

Table 5-1. CTR Take-Off-Settings

Distance from runway end, feet	0	1376	4126	6876	9626
Altitude	0	0	500	1,000	1,500
Speed	32	180	180	180	180
Thrust level	2	2	2	2	1

1 D. Conner, M. Marcolini, J. Edwards, and J. Brieger, "XV-15 Tiltrotor Low Noise Terminal Area Operations," Presented at the American Helicopter Society 53rd Annual Forum, Virginia Beach, VA: April 29-May 1, 1997.

D. Conner, Marcolini, Decker, Cline, Edwards, Nicks, and Klein, "XV-15 Tiltrotor Low Noise Approach Operations," Presented at the American Helicopter Society 55th Annual Forum, Montreal, Canada: May 25-27, 1999.

Table 5-2. CTR Approach Settings

Distance from runway end	20	10	5	3	1
Altitude	6,000	3,236	1,644	1,007	370
Speed	180	180	180	180	180
Thrust level	3	3	3	3	3

Table 5-3. Effective Perceived Noise Levels

Altitude (feet)	Thrust levels		
	1	2	3
500	90.2	101.70	112.00
1,000	85.8	98.26	105.80
1,500	83.1	96.97	104.00
2,250	79.4	95.20	102.10
3,000	73.7	93.44	101.30
3,850	67.6	92.51	100.50
4,700	63.1	88.81	98.63
6,000	56.8	86.46	94.72

Note: assumes an average CTR configuration of 6 percent glideslope, the noisiest profile possible for CTR.

We modeled existing (1999) traffic patterns against the model's 1993 population base, 2007 traffic patterns against the model's 2005 population base, and 2017 traffic patterns against the model's 2015 population base. The population and housing database is embedded in the INM and is used to calculate the number of persons and houses impacted when a noise contour falls across a given acreage. INM population and housing data are time-consuming to update; given the brief nature of this study we elected to use the closest possible year from previously defined datasets.

RESULTS, 1999 TRAFFIC

Newark

Adding CTRs to the fleet resulted in a generally noisier environment than exists with the existing aircraft fleet, at both Newark and Dulles; though in some cases noise actually decreased. These results should be viewed with caution, since much of the underlying data was assumed. Table 5-4 lists the percentage change in noise levels after replacing half of turboprops at Newark with CTRs. At the 75 dB level, substitution of CTRs caused noise levels to drop for housing and off-airport acreage. The column heading "Population" refers to the number of persons living in a noise-impacted area, for a particular level of noise. "Housing" refers to the number of houses in the noise-impacted area for a given contour. Both population and housing are based on the U.S. Census data for the given region. "Off airport impact area" lists the non-airport acres of land and water impacted by the given noise level, whether the land is developed or not. "Total impact area" lists total acres, both on airport grounds and non-airport, impacted by a given noise level. Table 5-5 reports the underlying decibel levels from which Table 5-4 was computed; the same column heading definitions apply.

Table 5-4. Percentage Change in Noise Levels with CTR, Newark 1999

Sound level (dB)	Change in population exposure (%)	Change in housing exposure (%)	Change in off-airport impact area (%)	Change in total impact area (%)
75	14.6	-40.0	-27.5	2.9
70	26.6	27.2	31.3	13.6
65	34.2	36.3	65.2	48.1
60	21.7	22.7	46.2	40.2
55	32.9	34.5	31.6	29.4

Table 5-5. Noise Levels, Newark 1999

	Without CTR				With CTR			
Sound level (dB)	Population	Housing	Off-airport impact area (acres)	Total impact area (acres)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)
75	19	9	95	1105	22	6	72	1137
70	8556	2575	876	2374	11178	3384	1201	2721
65	31473	9866	3377	5378	44471	14247	6642	8780
60	73269	24354	10854	13416	91112	30591	17367	20175
55	194861	70378	27883	31304	271507	99671	38358	42073

Figures 5-1 and 5-2 show pictorially how projected noise levels impact the area surrounding Newark airport. Dense population areas can be identified by a density of street lines; Newark Bay is also identifiable. In Figure 5-2 it is possible to see how sound fade impacted the noise contours in the model in the long noise "tail" extending out from runway 04. It is worth noting that sound fade is one of the parameters we had to draw from existing aircraft, as we do not have any data on the actual sound fade from CTRs. Thus, a significant increase in modeled noise is actually due from an assumed parameter; real results from the future CTR may be dramatically different.

Figure 5–1. Newark 1999 Baseline Noise Contours

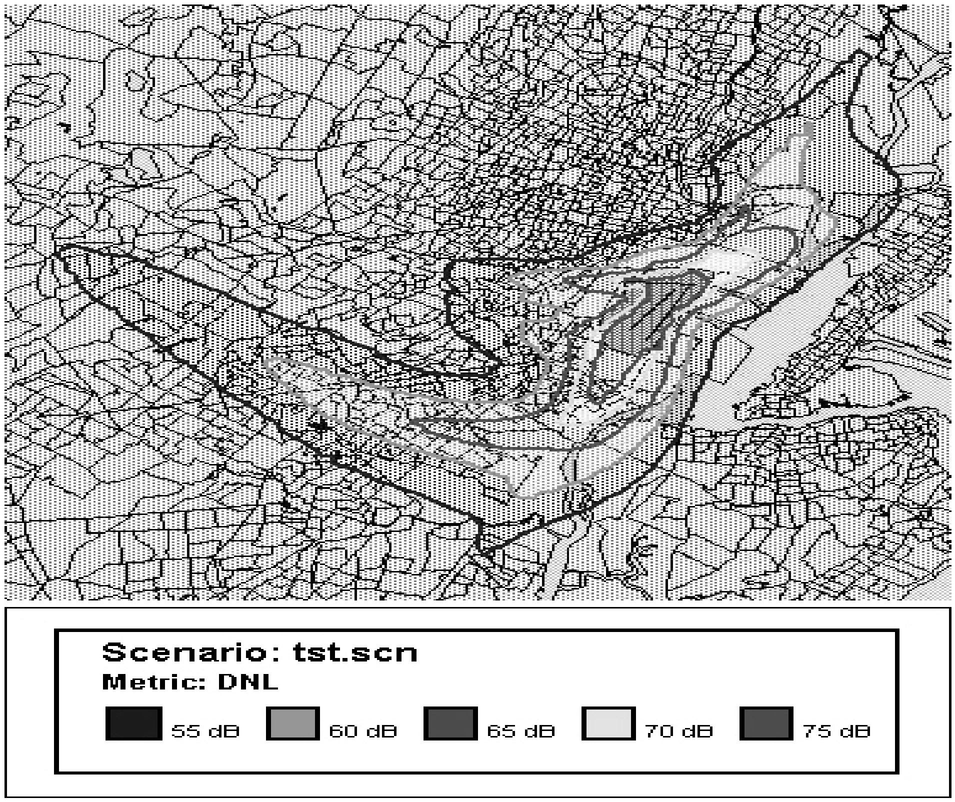


Figure 5–2. Newark with CTR 1999 Noise Contours

Dulles

Table 5-6 shows the percentage change in noise levels after replacing 50 percent of turboprops with CTRs at Dulles in the 1999 environment. Unlike Newark, there is a significant increase in persons affected by noise at all levels when CTRs are added to the fleet. Table 5-7 shows the decibel levels underlying the Table 5-6; i.e., the absolute number of persons, houses, and acres under each noise exposure level. Baseline and with-CTR noise levels are represented pictorially with noise contours in Figures 5-3 and 5-4.

Table 5-6. Percentage Change in Noise Levels with CTR, Dulles 1999

Sound level (dB)	Change in population exposure (%)	Change in housing exposure (%)	Change in off-airport impact area (%)	Change in total impact area (%)
75	89.7	85.7	35.8	6.7
70	81.4	84.2	43.8	20.4
65	104.7	108.6	55.1	39.1
60	47.9	49.2	35.2	30.3
55	30.2	30.0	26.5	24.5

Table 5-7. Noise Levels, Dulles 1999

	Without CTR				With CTR			
Sound level (dB)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)
75	48	16	449	4960	126	40	645	5306
70	2409	788	4184	11134	5716	1934	6529	13657
65	10343	3466	15397	24405	33078	11700	27108	36268
60	36612	12670	47149	57107	59655	20939	67297	77470
55	93566	32900	109747	120357	126902	44517	143237	153994

Figures 5-3 and 5-4 show pictorially how projected noise levels impact the area surrounding Dulles airport.

Figure 5–3. Dulles Baseline 1999 Noise Contours

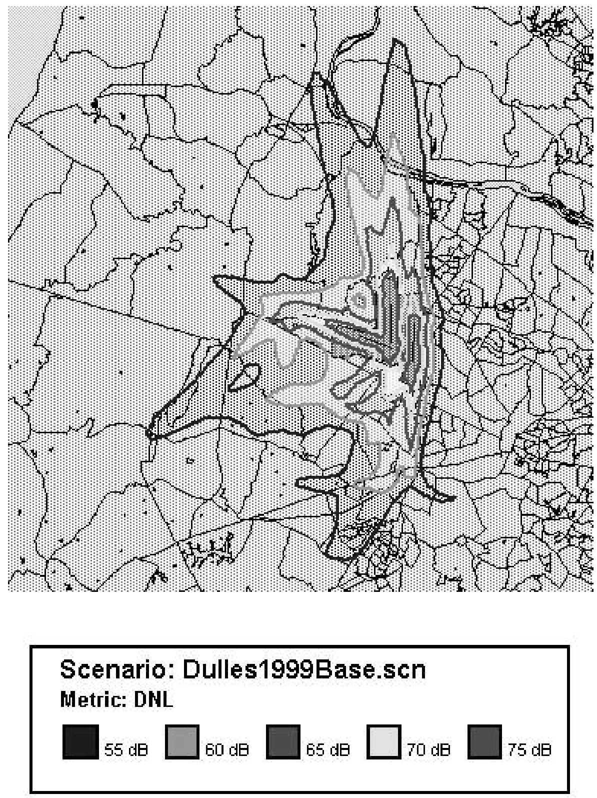
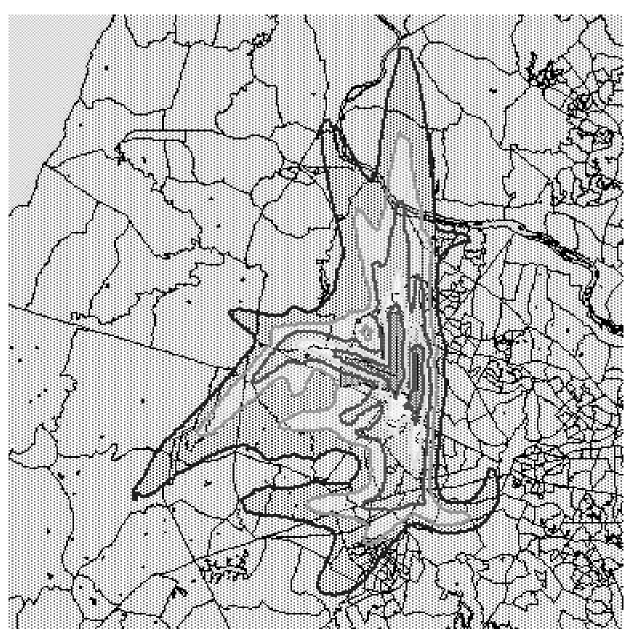


Figure 5–4. Dulles with CTR 1999 Noise Contours



RESULTS, 2007 TRAFFIC

Newark

In 2007, half of turboprop traffic was replaced with CTRs. Other than this replacement, the fleet mix of aircraft types was held constant as a simplifying assumption. Table 5-8 shows the percentage change in noise levels for the area surrounding Newark. Significantly more persons and land are affected by increased noise due to the addition of CTRs, according to the model and current inputs. Increases in affected population range from 38 percent at the quietest measurement (55 dB) to 62 percent at the 75 dB level.

Table 5-8. Percentage Change in Noise Levels with CTR, Newark 2007

Sound level (dB)	Change in population (%)	Change in housing (%)	Change in off-airport impact area (%)	Change in total impact area (%)
75	61.7	64.0	70.0	39.3
70	48.4	51.6	82.9	65.4
65	40.1	43.3	57.1	50.6
60	47.2	50.7	38.0	36.3
55	38.4	40.9	26.6	26.0

Table 5-9. Noise Levels, Newark 2007

	Without CTR				With CTR			
Sound level (dB)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)
75	12,006	3,711	1,174	2,756	22,706	7,204	2,438	4,102
70	33,972	10,814	4,123	6,232	55,681	18,331	9,962	12,290
65	82,914	28,304	12,380	15,081	124,498	43,941	22,273	25,308
60	226,334	82,456	31,838	35,406	366,031	138,451	46,787	51,125
55	561,050	206,686	74,548	80,642	827,647	312,790	97,435	104,769

The noise contours before and after adding CTRs to the fleet are depicted in Figures 5-5 and 5-6. Note that while the two figures are the same size, they are not drawn on the same scale; surrounding landmarks must be used to gauge the differences in impact between the two figures.

Figure 5–5. Newark Baseline 2007 Noise Contours

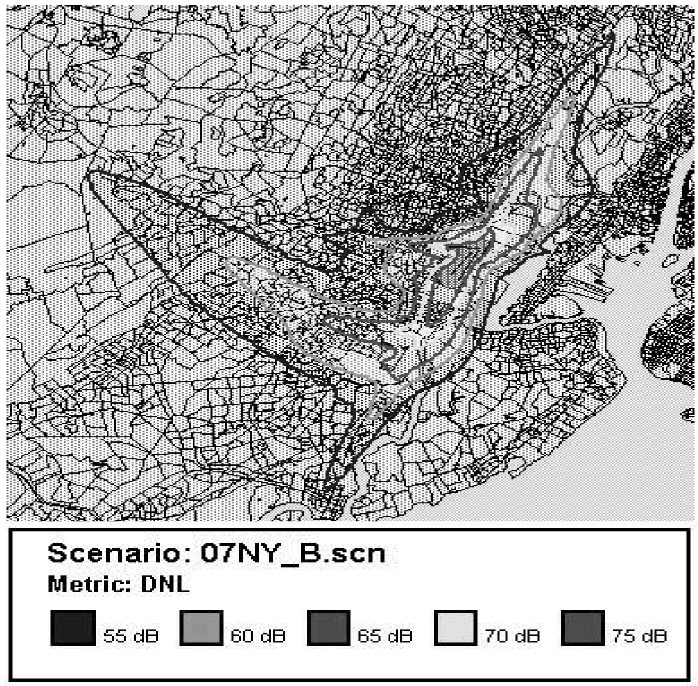
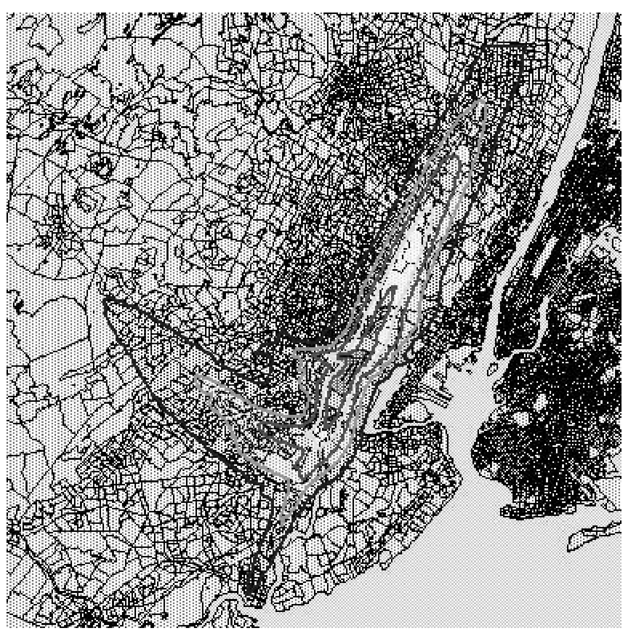


Figure 5–6. Newark With CTR 2007 Noise Contours



Dulles

Changes in noise levels due to CTR use at Dulles are substantial. A significant increase in the number of people subjected to the loudest noise levels is projected, both at the percentage level (see Table 5-10) and in absolute terms (see Table 5-11.) Note that percentage terms are computed over an average of the ex ante and ex post exposure numbers rather than over the ex ante.

Table 5-10. Percentage Change in Noise Levels with CTR, Dulles 2007

Sound level (dB)	Change in population exposure (%)	Change in housing exposure (%)	Change in off-airport impact area (%)	Change in total impact area (%)
75	170.4	168.8	99.4	24.0
70	149.2	151.7	97.3	56.0
65	118.9	122.3	79.7	60.9
60	80.7	80.6	52.9	46.5
55	42.4	40.5	42.0	39.3

Table 5-11. Noise Levels, Dulles 2007

	Without CTR				With CTR			
Sound level (dB)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)
75	102	35	547	5244	1277	414	1629	6672
70	3715	1267	4686	11843	25563	9234	13567	21051
65	14526	4989	16973	26062	57132	20678	39455	48865
60	50160	17906	50655	60642	118017	42083	87066	97388
55	136982	49321	117530	128267	210683	74344	179956	191044

Pictures of the existing noise contours surrounding Dulles are given in Figure 5–11; and Figure 5–12 shows noise contours as they are projected after the inclusion of CTRs in the fleet. The increase in affected area is visible by comparing the two maps. The difference is more pronounced than in New York for two reasons; first, maps are on a smaller scale (mileage) than in New York; and there are far more turboprops to replace operating out of Dulles.

Figure 5–7. Dulles Baseline 2007 Noise Contours

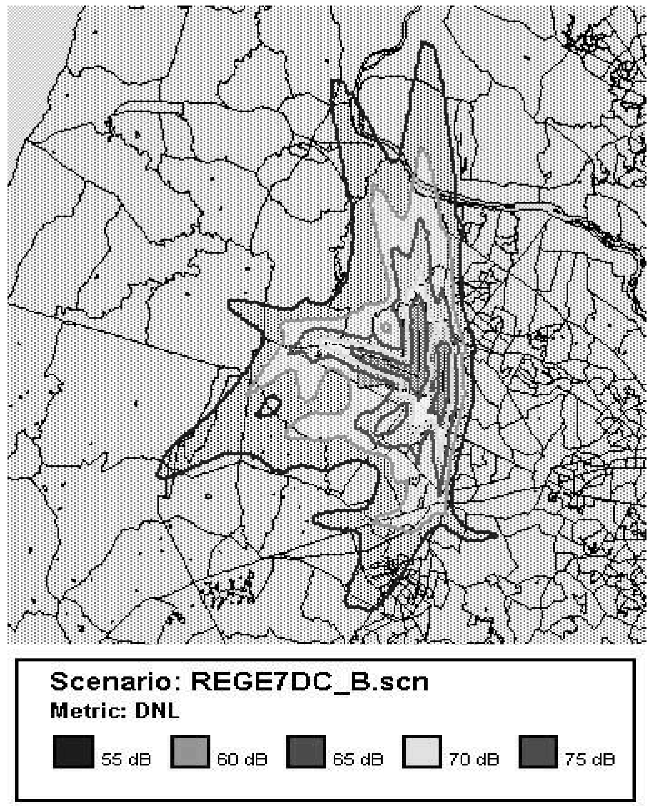
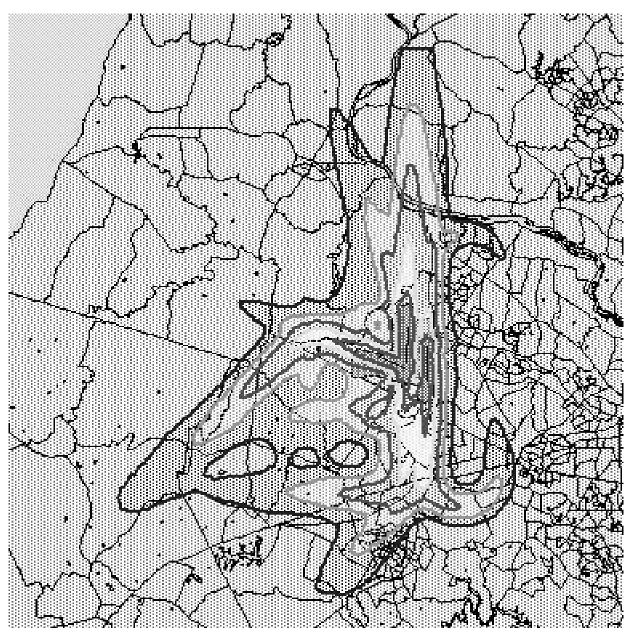


Figure 5–8. Dulles with CTR 2007 Noise Contours



RESULTS, 2017 TRAFFIC

Newark

In 2017, all turboprop traffic was replaced with CTRs. Other than this replacement, the fleet mix of aircraft types was held constant as a simplifying assumption. Table 5-12 shows the percentage change in noise levels for the area surrounding Newark. The increase in persons affected at all noise levels was significant.

Table 5-12. Percentage Change in Noise Levels With CTR, Newark 2017

Sound level (dB)	Change in population (%)	Change in housing (%)	Change in off-airport impact area (%)	Change in total impact area (%)
75	115.3	118.5	143.9	106.8
70	91.3	96.9	120.9	102.9
65	102.7	109.2	94.7	87.0
60	89.1	93.2	75.6	73.5
55	72.6	73.9	58.6	57.4

Table 5-13. Noise Levels, Newark 2017

	Without CTR				With CTR			
Sound level (dB)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)
75	12014	3677	1171	2780	44733	14374	7185	9153
70	34366	10840	4223	6364	92049	31220	17136	19855
65	82137	27699	12603	15312	255566	94372	35274	38909
60	230022	82777	32514	36136	599621	227123	72037	78101
55	585292	213529	76512	82877	1253026	464018	139940	149551

Figures 5-9 and 5-10 show how the noise contour levels would overlay the area surrounding Newark with and without CTRs in the fleet. Note that the two figures are drawn to different scales and local landmarks in the figures should be referenced when trying to determine comparative impact.

Figure 5–9. Newark Baseline 2017 Noise Contours

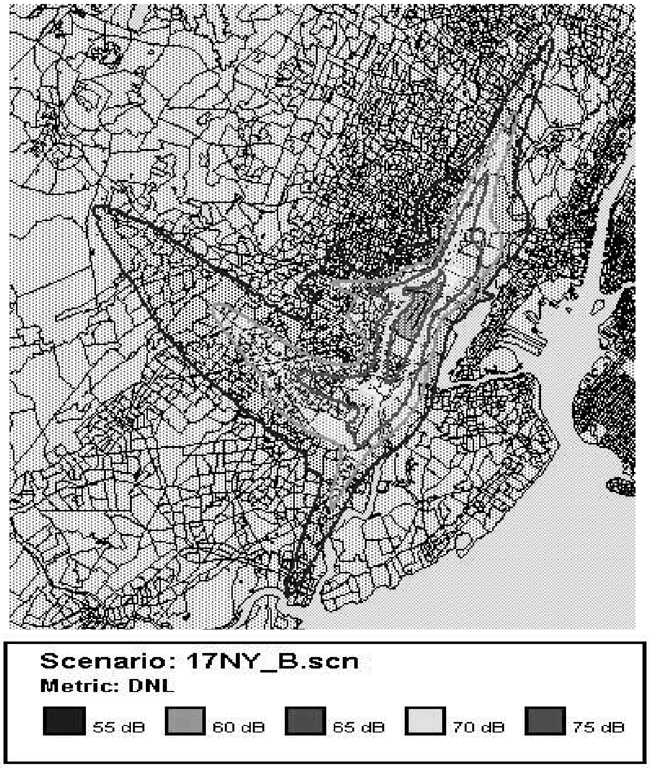
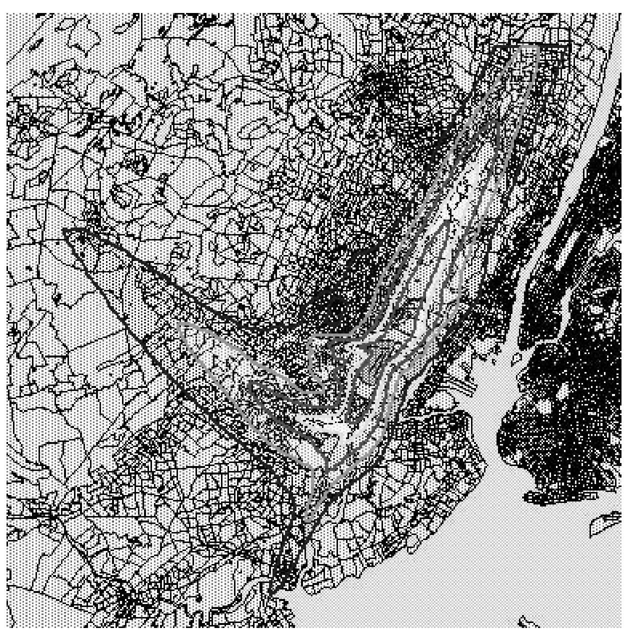


Figure 5–10. Newark with CTR 2017 Noise Contours



Dulles

Changes in noise levels due to CTR use at Dulles are substantial. A significant increase in the number of people subjected to the loudest noise levels is projected, both at the percentage level (see Table 5-14) and in absolute terms (see Table 5-15.) Note that percentage terms are computed over an average of the ex ante and ex post exposure numbers rather than over the ex ante.

Table 5-14. Percentage Change in Noise Levels with CTR, Dulles 2017

Sound level (dB)	Change in population exposure (%)	Change in housing exposure (%)	Change in off-airport impact area (%)	Change in total impact area (%)
75	192.7	193.1	146.9	48.2
70	165.6	167.8	126.3	79.0
65	130.1	133.1	101.6	79.1
60	93.2	95.2	69.0	61.1
55	60.5	61.2	58.3	55.2

Table 5-15. Noise Levels, Dulles 2017

	Without CTR				With CTR			
Sound level (dB)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)	Population	Housing	Off airport impact area (acres)	Total impact area (acres)
75	152	51	619	5222	8190	2912	4043	8540
70	4458	1527	4832	11876	47408	17463	21394	27398
65	17326	5946	17242	26262	81801	29620	52834	60606
60	59708	21280	51658	61655	163969	59947	106031	115839
55	170413	61427	120398	131175	318321	115546	219374	231113

A picture of the noise contours from 55 to 75 dB under a non-CTR projected fleet mix and traffic level for 2017 is shown in Figure 5-7. Comparing this picture with the projected noise levels with all turboprops replaced by CTRs shown in Figure 5-8, it is evident that noise levels have significantly increased.

Figure 5–11. Dulles Baseline 2017 Noise Contours

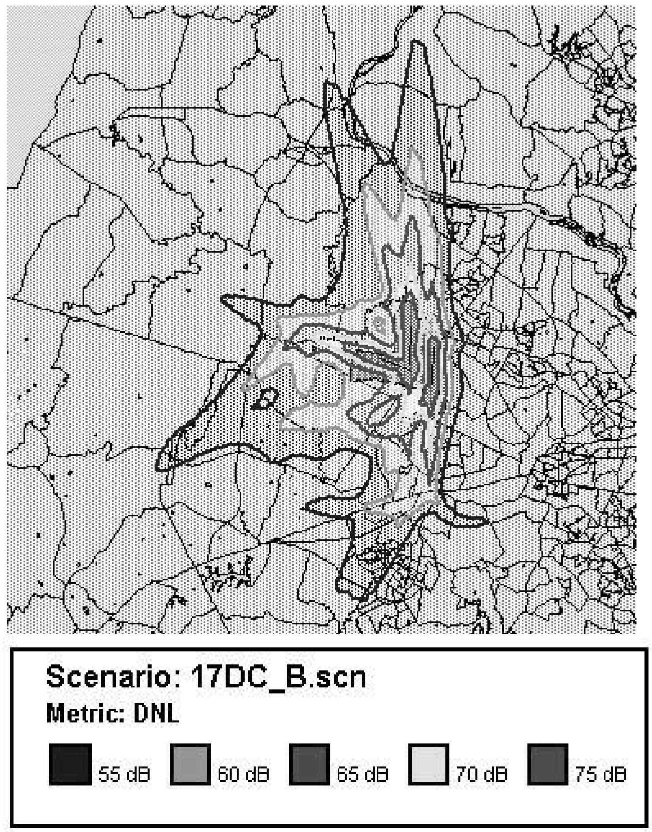
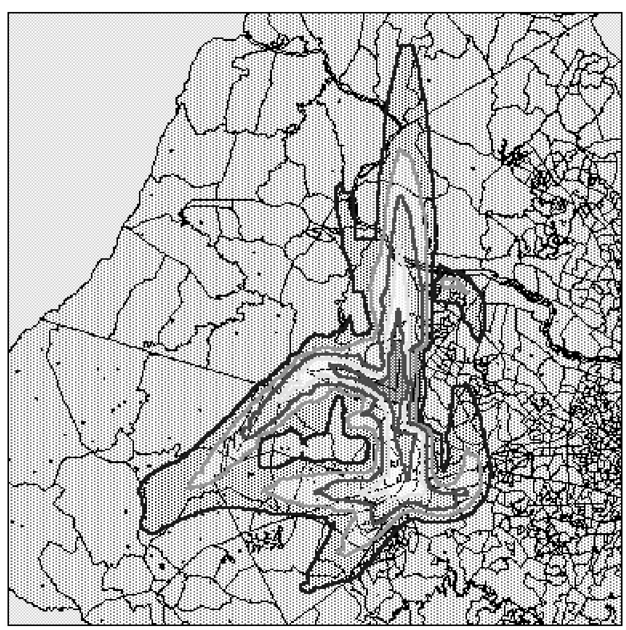


Figure 5–12. Dulles CTR 2017 Noise Contours



SUMMARY

We selected two parameters to summarize the noise results: increase in affected off-airport acreage and increase in affected population. Increase in affected population is probably the most politically important measurement when assessing the impact of adding CTRs to an airport. But since population density around an airport is increasing over time, increase in affected off-airport acreage is analytically a clearer way to gauge the actual noise increase due to greater CTR operations.

Using these metrics, the increase in affected population is significant at Dulles in all three time frames, and significant at Newark only in the future. Dulles shows greater noise impact than Newark, probably due to a smaller population base and to a greater percentage of turboprop flights in their traffic mix.

Figure 5-13 shows the percentage increases in affected acreage and population for Newark. The lines and points are coded so that all population data is shown with red lines and solid points; acreage is presented in blue lines with hollow point markers. The markedly different impacts at different decibel levels in the 1999 data reflects the quirkiness of actual residential trends; they smooth out in future predictions as a side effect of the predictive process.

Figure 5–13. Increases in Noise-Affected Population and Acres At Newark

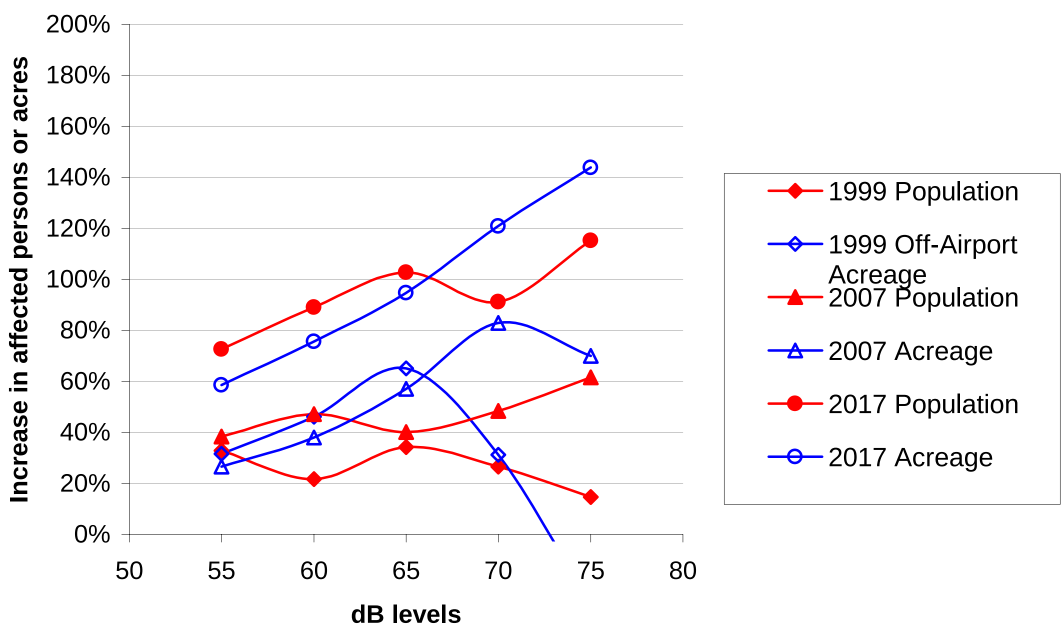
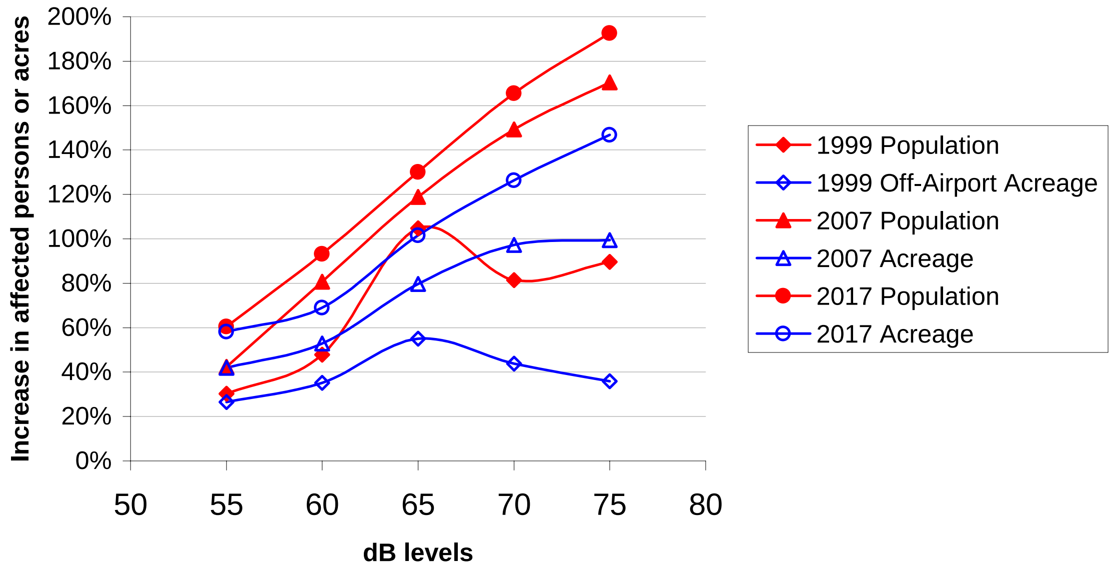


Figure 5-14 shows the percentage increases in affected acreage and population for Newark. The lines and points are coded so that all population data is shown with red lines and solid points; acreage is presented in blue lines with hollow point markers. The bump in the 1999 data is smoothed out over time as a side effect of the predictive process.

Figure 5–14. Increase in Noise-Affected Population and Acres At Dulles



Averaged out over all noise levels, CTR noise impacts 34 percent more off-airport acreage in 1999, 65 percent more off-airport acreage in 2007, and 100 percent more off-airport acreage in 2017. The increased noise impacts 59 percent more persons in 1999, 80 percent more in 2007, and 111 percent more in 2017. All this is engendered by an increase of roughly 5 percent of flights in 1999 and 2007 and 14 percent of flights in 2017.

Chapter 6
Market Feasibility Study

BASIC ASSUMPTIONS

Our economic modeling began with a survey of existing CTR studies. The Civil Tiltrotor Development Advisory Committee's Report to Congress (CTRDAC)[1] contained what we regarded as the most thought-out approach to CTR financing, and we tailored our model to its assumptions:

- $1.8 billion non-recurring (research & development) costs, of which $600 million is government funded (1994 dollars)
- Production run of 506 aircraft
- Aircraft selling price of $18.5 million (1994 dollars), or about $20 million in today's dollars
- First CTRs being offered for sale in 2010.

These assumptions lead to the development of an average price/marginal price set of cost curves. Following the analysis through, we find that the operating cost for CTRs is slightly higher than that for turboprops and higher than for regional jets. The implication is that CTRs will be used in particular markets, those congested enough or hard enough to reach that they will support a fare premium.

Assuming NASA development through 2005 and industry development beginning around 2005, the first CTRs could be available in 2010. If present trends continue, it would be several more years after that before commuter airlines would be able to afford used CTRs and add them to their fleets.

We sorted the Official Airline Guide (OAG) and searched for turboprop flights serving market pairs 500 miles apart and less. These markets flights would be candidates for replacement by CTRs. The 500-mile restriction was imposed so that the CTR would have adequate fuel reserves onboard to comply with FAA restrictions, given its 600-mile range. Forty-eight aircraft in the current schedule in Newark and Dulles markets were candidates for replacement. In identifying turboprop routes, we ran across an interesting phenomena: a market beyond the parameters of the CTRs. The "snowbird" market, consisting of flights from Canadian cities to cities in the southern United States, are served by turboprops but have greater distances than the CTRs 500-mile range.

[1] Civil Tiltrotor Development Advisory Committee Report To Congress, U.S. Department of Transportation: December 1995.

This evaluation framework of the Capacity Pillar Goal seeks to free capacity in the NAS by first substituting Civil Tilt Rotor (CTR) aircraft for turboprop and possibly turbojet aircraft, then reallocating that portion of system capacity to jet aircraft.

DERIVATION OF COST

Let us first examine the manufacturing economics of the CTR. The CTR design under consideration is a 40 passenger aircraft with a 600 nautical mile range (720 statute miles) and a cruising speed of 315 knots (360 miles per hour). It has a purchase price of $18.5 million at the breakeven point of 506 aircraft. The development program fixed costs are $1.2 billion and the variable costs on the aircraft produced up to the breakeven point are $8.05 billion. The learning curve structure is 90 percent after reaching breakeven and 85 percent before.[2]

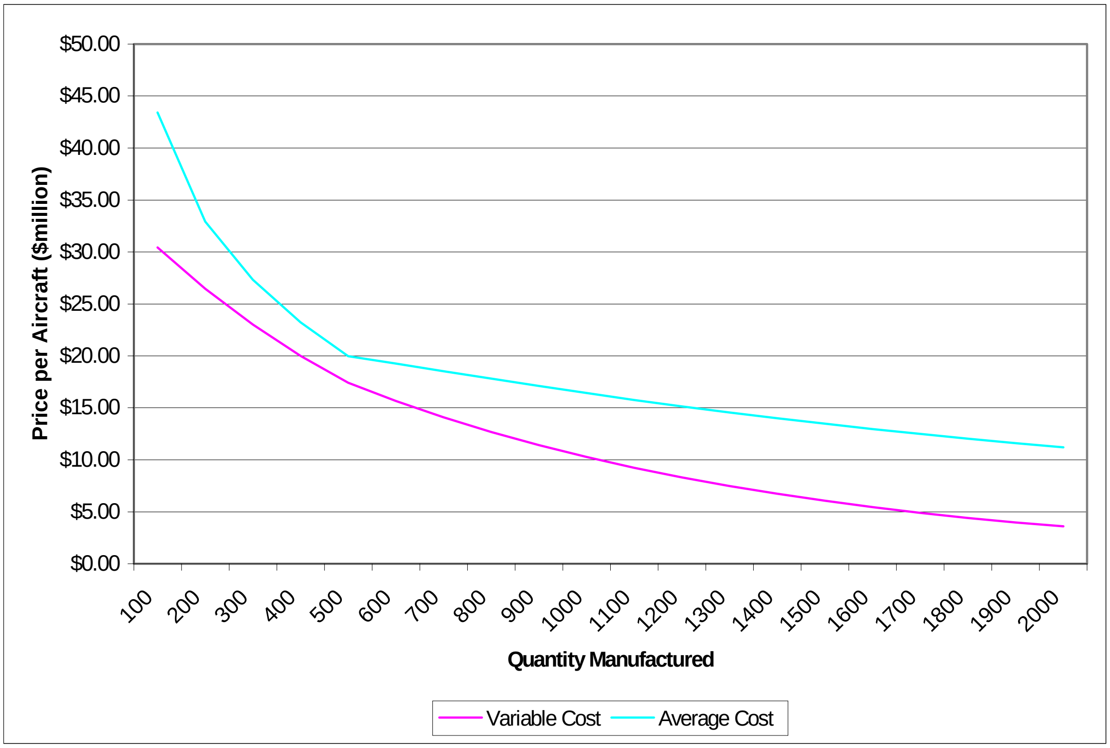
This data is used to calculate the approximate price-quantity curve shown in Table 2-1 and Figure 2-1. It is slightly biased towards a higher price as the marginal cost of the 500th aircraft (the breakeven aircraft) is not known. The average variable cost of the first 500 aircraft is used instead. Because it is an average it must be higher than the marginal cost of the 500th aircraft, hence the bias.

Table 6-1. Derived Cost Per CTR

Number of aircraft	Variable cost per aircraft in 1999 dollars ($)	Average cost per aircraft in 1999 dollars ($)
100	30,428,532	43,395,696
200	26,459,593	32,943,175
300	23,008,342	27,330,730
400	20,007,254	23,249,045
500	17,397,612	19,991,045
600	15,657,851	19,268,846
700	14,092,066	18,529,306
800	12,682,859	17,798,500
900	11,414,573	17,089,175
1000	10,273,116	16,407,569
1100	9,245,804	15,756,499
1200	8,321,224	15,136,893
1300	7,489,101	14,548,601
1400	6,740,191	13,990,858
1500	6,066,172	13,462,545
1600	5,459,555	12,962,359
1700	4,913,599	12,488,902
1800	4,422,240	12,040,754
1900	3,980,016	11,616,505
2000	3,582,014	11,214,780

[2] This financial data is all in 1994 dollars. These were normalized to 1999 dollars by use of the Bureau of Labor Statistic’s Aircraft and Parts Index

Figure 6–1. Quantity Versus Price Curve



This price-quantity curve, to a large degree, determines the manufacturers willingness build the vehicle, and the potential profits from the project. A minimum number of aircraft sales are usually needed to launch the vehicle line. In this case it is 500 aircraft over the first 10 years, at almost $20 million a copy.

The next issue is to examine operator economics. The fundamental concept is that operators will only purchase new aircraft if they can make a profit with those aircraft. In general, leisure travelers are sensitive to fares while business travelers are sensitive to schedules. The basic assumption is that CTRs will be more expensive to operate than either turboprop or turbojet aircraft. The differences can be dramatic. CTR costs are estimated to be $0.29 per ASM. Small aircraft, serving short haul routes for minor airlines have costs between $0.243 per ASM (US Air Shuttle) and $0.139 per ASM (Atlantic Southeast). The major airlines operating similar stage lengths have costs between $0.115 per ASM (US Air) and $0.072 per ASM (Southwest). The CTRDAC analysis assumes that passengers are willing to pay this premium. This may be an overly optimistic assumption. If that assumption is not true, then the CTR operations are feasible and profitable only when turboprop and turbojet aircraft are forced out of major airports by a change in the rules and regulations and CTR operations are the only available option in these markets.

SUBSTITUTION OF CTRS FOR EXISTING AIRCRAFT

The next analysis looks at the number of CTRs used to service Dulles and Newark. These two markets are very important as they represent ideal markets for CTR operations. These markets are already operating at or near capacity, and delays are expected to only increase in the future. They are also located on the north eastern corridor, which means that they will have the highest frequency and usage patterns.

The demand for CTR service in these markets is calculated under two sets of assumptions. The first is that CTR service is used to replace all turboprop aircraft, the second is that both turboprop and turbojet aircraft are replaced by CTRs. Both analyses are for the baseline year, 1999.

Three methods are used to calculate CTR demand in those two markets:

- replacement of seat capacity;
- replacement of schedule;
- aircraft productivity.

Replacement of seat capacity

This method simply calculates the number of seats on turboprop and turbojet aircraft used to service the two airports from within 600 miles and finds the equivalent number of CTRs to supply the same seats.

This method yields a rather large number of CTRs but can be inaccurate due to the low load factors on most of these short haul flights (around 30 percent)

Table 6-2. CTR Substitution Via Sect Replacement Method

Airport	Method	
	Seat replacement turboprop only	Seat replacement turboprop and turbojet
Newark	40.0	54.0
Dulles	8.5	15.1

Replacement of schedule

This method calculates the number of CTRs needed by each airline to fly exactly the same schedule. Then the total number of aircraft needed is found by summing across all carriers.

Table 6-3. CTR Substitution Via Schedule Replacement Method

Airport	Method	
	Schedule replacement turboprop	Schedule replacement turboprop and turbojet
Newark	29	44
Dulles	9	14

The analysis of the actual OAG traffic schedule for the month of September 1999 also presents an interesting phenomenon. There is a gap in coverage if all the turbojets removed from service, i.e. there are markets currently served by turbojets that are too distant to be served by CTRs. Furthermore some of these markets do not have the demand profile suitable for regular jet service.

Analysis of daily operations at EWR and IAD looks at the maximum level of CTR usage achievable at those airports.[3] The sum of the percentage of turbojet and turboprop operations represent the maximum percentage of CTR aircraft servicing that airport. This calculation implicitly assumes that each arrival/departure operation pair is performed by a single aircraft. In reality, a single turboprop/turbojet aircraft may fly several operations out of a hub airport each day. When this factor is accounted for, the number of replaceable aircraft drops to between 10 percent and 8 percent of the aircraft servicing both airports.

Table 6-4. CTR Substitution Via CTR Minimization

Airport	Method						
	Total ops	TP ops (%)	TJ ops (%)	TJ & TP ops per day			
				1	2	3	4
Dulles	1105	30	1	31%	15.5%	10.3%	7.8%
Newark	1265	22	8	30%	15.0%	10.0%	7.5%

The economic viability of the CTR exists on a set of tenuous circumstances. The safety of the aircraft has yet to be proven to the standards of the commercially existing aircraft. Safety is of paramount concern to most of the flying public; and new aircraft design must be proven to be as good as the existing fleet.

If that problem is solved, the issue becomes one of fundamental economics. The CTRs are designed to replace turboprop aircraft. The turboprop fleet is largely owned by second tier airlines, those whose balance sheets are much less likely to be able to carry the payments associated with new aircraft, and operate in markets

[3] Note that this paragraph discusses flights arriving and departing at Newark and Dulles airports only; though the Newark and Dulles terminal *areas* were modeled. The number of flights in and out of the terminal areas is roughly triple that of the traffic in and out of each single airport.

that are only profitable using used aircraft. These carriers would ideally favor the purchase of used aircraft, but used CTR aircraft are unlikely to be available until 10 years after their initial introduction.

This is a somewhat strange result in that the target market for this aircraft is the one least able to afford it. Furthermore, as demand increases to justify service, turbojet aircraft have better operating economics than CTR.

Initial calculations show a likely fare premium for CTR service. This fare premium is expected to drive down demand. A portion of the leisure market can then be expected to switch to other transport modes, as those modes begin to exploit the fare premium. This fare premium problem can be somewhat alleviated on routes where the CTR is used on a portion of the flight legs. But CTR-only routes may make alternative modes of transportation the preferred travel mode.

A way around the whole economic viability issue is by legal fiat. If turboprop aircraft were denied access to the runways at major airports, the CTRs become viable, regardless of the price. The CTR would now be economically viable, at least initially, as the market for financing, including sales and leasing, would develop. Of course, this market, at both the input and output levels, would share behavioral aspects like any other legally imposed monopoly, but attenuated because of its peculiar role and placement within the competitive air transportation field.

References

[1] D. Conner, M. Marcolini, J. Edwards, and J. Brieger. “XV-15 Tiltrotor Low Noise Terminal Area Operations,” Presented at the American Helicopter Society 53rd Annual Forum, Virginia Beach, VA: April 29-May 1, 1997.

[2] D. Conner, Marcolini, Decker, Cline, Edwards, Nicks, and Klein, “XV-15 Tiltrotor Low Noise Approach Operations,” Presented at the American Helicopter Society 55th Annual Forum, Montreal, Canada: May 25-27, 1999.

Appendix A
CTR Performance Data File for Airspace Simulation

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109                        # INDEX, NASA CIVIL TILT-ROTOR
CTR  S  2  4   M  M        # Type, Haul, Wake Turb.Cat., Classif., Performance Cat (SID, STAR)
030  280  320              # Preferable levels (Low, High), Ceiling (FL)

005  040  115  130  0.0  0.0  0.0  36   # Below level... Min,Norm,Max Climb.IAS(kt) Mach, Fuel Consump.
015  100  170  190  0.0  0.0  0.0  70
030  130  230  250  0.0  0.0  0.0  64
050  130  250  250  0.0  0.0  0.0  60
100  130  250  250  0.0  0.0  0.0  58
200  130  300  320  0.0  0.0  0.0  51
250  130  300  335  0.0  0.0  0.0  42
270  130  300  350  0.0  0.0  0.0  36
320  0.0  0.0  0.0  0.65 0.70 0.75  35

005  040  115  130  0.0  0.0  0.0  36   # Below level... Min,Norm,Max Cruise.IAS(kt) Mach, Fuel Consump.
015  100  170  190  0.0  0.0  0.0  36
030  130  230  250  0.0  0.0  0.0  36
050  130  250  270  0.0  0.0  0.0  36
100  130  300  320  0.0  0.0  0.0  33
200  130  300  335  0.0  0.0  0.0  33
250  130  300  335  0.0  0.0  0.0  33
270  140  300  350  0.0  0.0  0.0   22
320  0.0  0.0  0.0  0.74 0.79 0.84  22

005  2000  2500  5.0  5.9          # Below level... Norm,Max Climb(ft/m) & Turn(d/s) Rate
015  2000  2500  5.0  5.9
030  1200  2500  4.0  4.9
050  1500  3000  3.0  3.9
100  1500  2500  2.0  2.6
200  1500  2000  2.0  2.6
250  1500  2000  2.0  2.6
270  2000  2000  2.0  3.0
320  1400  1700  1.0  1.5
```

```
0.9                                  # IAS/Rate-of-climb Factor (IAS drops if ROC increased)

 005  010  030  090  0.0  0.0  0.0  15   # Below level... Min,Norm,Max Desc.IAS(kt) Mach, Fuel C.
015  070  070  090  0.0  0.0  0.0  15
030  100  120  200  0.0  0.0  0.0  15
050  130  170  250  0.0  0.0  0.0  15
100  130  245  250  0.0  0.0  0.0  15
200  130  260  280  0.0  0.0  0.0  10
250  130  280  335  0.0  0.0  0.0   5
270  130  300  350  0.0  0.0  0.0   4
320  0.0  0.0  0.0  0.73 0.78 0.83  4

005  0100  1000                          # Below level... Norm,Max Desc. Rate(ft/min)
015  1000  2000
030  1500  2000
050  1500  2000
100  2000  2500
200  2000  2500
250  2000  2500
270  2400  2900
320  2900  3500

30  050  080  050  070                  # Airborne Speed; Norm,Max Accel. & Decel. (kt/min)

005  50                              # HOLDING-SPEEDs.
015  130
030  130
050  130
100  170
200  170
250  250
270  250
320  280

70  90  20  50                          # Norm,Max IAS on Fin.approach & on Touchdown (kt)
5.0  5.0  5.0                           # Ground accel., decel  dry/wet (m/s/s)
```

```
20   30   55                    # Norm., Rapid exit, Cornering taxiing speeds (kt)
30  30  30  30                  # Min RWY length: T-off wet/dry, Land wet/dry (m)

10   5   0.5                    # Max. Alt.(ft), TAS(kt), Rate-of-turn (deg) Errors

1    1    1    1    1    0    0     # ndb  vor  dme  ils  ins omega navstar
40    0    0    0    350  0         # npax,percbpax,paxvotbus,paxvotlei,nfuelcost,fuelcost
```

Appendix B

TAAM Data Files

```
NewYork_VFR_NASA.prj

# single_terminal
#data/map/gtool
JFK_RADAR.pol
EWR_RADAR.pol
atcmap3.pol
ny_tracon.pol
globe_new.pol
zdcsecs.pol
zbwsecs.pol
znysecs.pol
TEB.pol
#data/map/3d
#data/wpt
usa_all.WPT
#data/apt
tim_airports.APT
#data/rts
pref_routes1.RTS
#data/acf
Boeing_NYClean.ACF
#data/apt/KTEB/layouts
TEB.pol
#data/apt/KTEB/usage
KTEB.usg
```

```
NewYork_VFR_CTR

# single_terminal
#data/map/gtool
JFK_RADAR.pol
EWR_RADAR.pol
atcmap3.pol
ny_tracon.pol
globe_new.pol
zdcsecs.pol
zbwsecs.pol
znysecs.pol
TEB.pol
#data/map/3d
#data/wpt
usa_all.WPT
#data/apt
tim_airports.APT
#data/rts
pref_routes1.RTS
#data/acf
NY99ctr.ACF
#data/apt/KTEB/layouts
TEB.pol
#data/apt/KTEB/usage
KTEB.usg
```

```
NewYork_IFR_NASA

# single_terminal
#data/map/gtool
JFK_RADAR.pol
EWR_RADAR.pol
atcmap3.pol
ny_tracon.pol
globe_new.pol
zdcsecs.pol
zbwsecs.pol
znysecs.pol
TEB.pol
#data/map/3d
#data/wpt
usa_all.WPT
#data/apt
tim_airports.APT
#data/rts
pref_routes1.RTS
#data/acf
Boeing_NYClean.ACF
#data/apt/KTEB/layouts
TEB.pol
#data/apt/KTEB/usage
KTEB.usg
```

```
NewYork_IFR_CTR

# single_terminal
#data/map/gtool
JFK_RADAR.pol
EWR_RADAR.pol
atcmap3.pol
ny_tracon.pol
globe_new.pol
zdcsecs.pol
zbwsecs.pol
znysecs.pol
TEB.pol
#data/map/3d
#data/wpt
usa_all.WPT
#data/apt
tim_airports.APT
#data/rts
pref_routes1.RTS
#data/acf
NY99ctr.ACF
#data/apt/KTEB/layouts
TEB.pol
#data/apt/KTEB/usage
KTEB.usg
```

```
NewYork_VFR

NB: Runway usage

KEWR
   22L J,T arr
   22R J,T dep
   11  T arr
   29  T dep
KJFK
   13L arr, dep
   13R arr, dep
   22L arr
KLGA
   22 J,T arr
   13 J,T dep
```

```
NewYork_VFR_CTR

NB: Runway usage
    CTRs as Turbos
KEWR
   22L J,T arr
   22R J,T dep
   11  T arr
   29  T dep
KJFK
   13L arr, dep
   13R arr, dep
   22L arr
KLGA
   22 J,T arr
   13 J,T dep
```

```
NewYork_IFR

NB: Runway usage

KEWR
   22L J,T arr
   22R J,T dep

KJFK
   22L arr
   22R dep

KLGA
   22 J,T arr
   13 J,T dep
```

```
NewYork_IFR_CTR

NB: Runway usage
    CTRs as Turbos
KEWR
   22L J,T arr
   22R J,T dep
   23 CTR arr, dep

KJFK
   22L arr
   22R dep

KLGA
   22 J,T arr
   13 J,T dep
```

```
EWR_VFR
#data/apt/KLGA/layouts
KLGA.pol
#data/apt/KLGA/stars
KLGA_22_SWANN_1.sta
KLGA_22_RKA_1.sta
KLGA_22_PALEO_1.sta
KLGA_22_MINKS_1.sta
KLGA_22_MIP_1.sta
KLGA_22_EXTOL_1.sta
KLGA_22_CTR_1.sta
KLGA_22_BAF_1.sta
KLGA_22_ALB_1.sta
#data/apt/KLGA/sids
KLGA_13_PARKE_1.sid
KLGA_13_NEION_1.sid
KLGA_13_MERIT_1.sid
KLGA_13_LANNA_1.sid
KLGA_13_HAAYS_1.sid
KLGA_13_GREKI_1.sid
KLGA_13_GAYEL_1.sid
KLGA_13_ELIOT_1.sid
KLGA_13_DIXIE_1.sid
KLGA_13_COATE_1.sid
KLGA_13_BIGGY_1.sid
KLGA_13_BAYYS_1.sid
#data/apt/KLGA/usage
KLGA_VFR.usg
```

```
EWR_VFR_CTR
#data/apt/KLGA/layouts
KLGA.pol
#data/apt/KLGA/stars
KLGA_22_SWANN_1.sta
KLGA_22_RKA_1.sta
KLGA_22_PALEO_1.sta
KLGA_22_MINKS_1.sta
KLGA_22_MIP_1.sta
KLGA_22_EXTOL_1.sta
KLGA_22_CTR_1.sta
KLGA_22_BAF_1.sta
KLGA_22_ALB_1.sta
#data/apt/KLGA/sids
KLGA_13_PARKE_1.sid
KLGA_13_NEION_1.sid
KLGA_13_MERIT_1.sid
KLGA_13_LANNA_1.sid
KLGA_13_HAAYS_1.sid
KLGA_13_GREKI_1.sid
KLGA_13_GAYEL_1.sid
KLGA_13_ELIOT_1.sid
KLGA_13_DIXIE_1.sid
KLGA_13_COATE_1.sid
KLGA_13_BIGGY_1.sid
KLGA_13_BAYYS_1.sid
#data/apt/KLGA/usage
KLGA_VFR.usg
```

```
EWR_IFR
#data/apt/KLGA/layouts
KLGA.pol
#data/apt/KLGA/stars
KLGA_22_SWANN_1.sta
KLGA_22_RKA_1.sta
KLGA_22_PALEO_1.sta
KLGA_22_MINKS_1.sta
KLGA_22_MIP_1.sta
KLGA_22_EXTOL_1.sta
KLGA_22_CTR_1.sta
KLGA_22_BAF_1.sta
KLGA_22_ALB_1.sta
#data/apt/KLGA/sids
KLGA_13_PARKE_1.sid
KLGA_13_NEION_1.sid
KLGA_13_MERIT_1.sid
KLGA_13_LANNA_1.sid
KLGA_13_HAAYS_1.sid
KLGA_13_GREKI_1.sid
KLGA_13_GAYEL_1.sid
KLGA_13_ELIOT_1.sid
KLGA_13_DIXIE_1.sid
KLGA_13_COATE_1.sid
KLGA_13_BIGGY_1.sid
KLGA_13_BAYYS_1.sid
#data/apt/KLGA/usage
KLGA_IFR.usg
```

```
EWR_IFR_CTR
#data/apt/KLGA/layouts
KLGA.pol
#data/apt/KLGA/stars
KLGA_22_SWANN_1.sta
KLGA_22_RKA_1.sta
KLGA_22_PALEO_1.sta
KLGA_22_MINKS_1.sta
KLGA_22_MIP_1.sta
KLGA_22_EXTOL_1.sta
KLGA_22_CTR_1.sta
KLGA_22_BAF_1.sta
KLGA_22_ALB_1.sta
#data/apt/KLGA/sids
KLGA_13_PARKE_1.sid
KLGA_13_NEION_1.sid
KLGA_13_MERIT_1.sid
KLGA_13_LANNA_1.sid
KLGA_13_HAAYS_1.sid
KLGA_13_GREKI_1.sid
KLGA_13_GAYEL_1.sid
KLGA_13_ELIOT_1.sid
KLGA_13_DIXIE_1.sid
KLGA_13_COATE_1.sid
KLGA_13_BIGGY_1.sid
KLGA_13_BAYYS_1.sid
#data/apt/KLGA/usage
KLGA_IFR.usg
```

```
EWR_VFR
#data/apt/KJFK/layouts
KJFK.pol
#data/apt/KJFK/stars
KJFK_13L_WHALE_1.sta
KJFK_13L_TUSKY_1.sta
KJFK_13L_TOPPS_1.sta
KJFK_13L_TAFFY_1.sta
KJFK_13L_SIE_1.sta
KJFK_13L_ROBER_1.sta
KJFK_13L_RKA_1DL.sta
KJFK_13L_POGGO_1.sta
KJFK_13L_PLYMM_1DL.sta
KJFK_13L_LVZ_1DL.sta
KJFK_13L_LENDY_1.sta
KJFK_13L_IGN_1.sta
KJFK_13L_HNK_1.sta
KJFK_13L_ENE_1.sta
KJFK_13L_EBONY_1.sta
KJFK_13L_DNY_1DL.sta
KJFK_13L_CAMRN_1.sta
KJFK_13L_AVP_1.sta
KJFK_13L_ALB_1DL.sta
KJFK_13R_ALB_1.sta
KJFK_13R_CAMRN_1.sta
KJFK_13R_DNY_1.sta
KJFK_13R_ENE_1.sta
KJFK_13R_IGN_1.sta
KJFK_13R_LENDY_1.sta
KJFK_13R_LVZ_1.sta
KJFK_13R_OWENZ_1.sta
KJFK_13R_PLYMM_1.sta
KJFK_13R_RKA_1.sta
KJFK_13R_ROBER_1.sta
KJFK_13R_TUSKY_1.sta
KJFK_13R_SIE_1.sta
KJFK_13R_POGGO_1.sta
KJFK_13R_WHALE_1.sta
KJFK_13R_HNK_1.sta
KJFK_13R_CCC_1.sta
```

```
EWR_VFR_CTR
#data/apt/KJFK/layouts
KJFK.pol
#data/apt/KJFK/stars
KJFK_13L_WHALE_1.sta
KJFK_13L_TUSKY_1.sta
KJFK_13L_TOPPS_1.sta
KJFK_13L_TAFFY_1.sta
KJFK_13L_SIE_1.sta
KJFK_13L_ROBER_1.sta
KJFK_13L_RKA_1DL.sta
KJFK_13L_POGGO_1.sta
KJFK_13L_PLYMM_1DL.sta
KJFK_13L_LVZ_1DL.sta
KJFK_13L_LENDY_1.sta
KJFK_13L_IGN_1.sta
KJFK_13L_HNK_1.sta
KJFK_13L_ENE_1.sta
KJFK_13L_EBONY_1.sta
KJFK_13L_DNY_1DL.sta
KJFK_13L_CAMRN_1.sta
KJFK_13L_AVP_1.sta
KJFK_13L_ALB_1DL.sta
KJFK_13R_ALB_1.sta
KJFK_13R_CAMRN_1.sta
KJFK_13R_DNY_1.sta
KJFK_13R_ENE_1.sta
KJFK_13R_IGN_1.sta
KJFK_13R_LENDY_1.sta
KJFK_13R_LVZ_1.sta
KJFK_13R_OWENZ_1.sta
KJFK_13R_PLYMM_1.sta
KJFK_13R_RKA_1.sta
KJFK_13R_ROBER_1.sta
KJFK_13R_TUSKY_1.sta
KJFK_13R_SIE_1.sta
KJFK_13R_POGGO_1.sta
KJFK_13R_WHALE_1.sta
KJFK_13R_HNK_1.sta
KJFK_13R_CCC_1.sta
```

```
EWR_IFR
#data/apt/KJFK/layouts
KJFK.pol
#data/apt/KJFK/stars
KJFK_22L_SIE_1DL.sta
KJFK_22L_ROBER_1.sta
KJFK_22L_RKA_1DL.sta
KJFK_22L_PLYMM_1DL.sta
KJFK_22L_OWENZ_1.sta
KJFK_22L_LVZ_1DL.sta
KJFK_22L_LENDY_1.sta
KJFK_22L_IGN_1DL.sta
KJFK_22L_ENE_1DL.sta
KJFK_22L_DNY_1DL.sta
KJFK_22L_CAMRN_3.sta
KJFK_22L_CAMRN_1.sta
KJFK_22L_ALB_1DL.sta
```

```
EWR_IFR_CTR
#data/apt/KJFK/layouts
KJFK.pol
#data/apt/KJFK/stars
KJFK_22L_SIE_1DL.sta
KJFK_22L_ROBER_1.sta
KJFK_22L_RKA_1DL.sta
KJFK_22L_PLYMM_1DL.sta
KJFK_22L_OWENZ_1.sta
KJFK_22L_LVZ_1DL.sta
KJFK_22L_LENDY_1.sta
KJFK_22L_IGN_1DL.sta
KJFK_22L_ENE_1DL.sta
KJFK_22L_DNY_1DL.sta
KJFK_22L_CAMRN_3.sta
KJFK_22L_CAMRN_1.sta
KJFK_22L_ALB_1DL.sta
```

EWR_VFR	EWR_VFR_CTR	EWR_IFR	EWR_IFR_CTR
KJFK_13R_EBONY_1.sta	KJFK_13R_EBONY_1.sta	#	#
KJFK_13R_FRILL_1.sta	KJFK_13R_FRILL_1.sta		
KJFK_13R_TOPPS_1.sta	KJFK_13R_TOPPS_1.sta		
KJFK_13R_TAFFY_1.sta	KJFK_13R_TAFFY_1.sta		
KJFK_22L_SIE_1DL.sta	KJFK_22L_SIE_1DL.sta		
KJFK_22L_ROBER_1.sta	KJFK_22L_ROBER_1.sta		
KJFK_22L_RKA_1DL.sta	KJFK_22L_RKA_1DL.sta		
KJFK_22L_PLYMM_1DL.sta	KJFK_22L_PLYMM_1DL.sta		
KJFK_22L_OWENZ_1.sta	KJFK_22L_OWENZ_1.sta		
KJFK_22L_LVZ_1DL.sta	KJFK_22L_LVZ_1DL.sta		
KJFK_22L_LENDY_1.sta	KJFK_22L_LENDY_1.sta		
KJFK_22L_IGN_1DL.sta	KJFK_22L_IGN_1DL.sta		
KJFK_22L_ENE_1DL.sta	KJFK_22L_ENE_1DL.sta		
KJFK_22L_DNY_1DL.sta	KJFK_22L_DNY_1DL.sta		
KJFK_22L_CAMRN_3.sta	KJFK_22L_CAMRN_3.sta		
KJFK_22L_CAMRN_1.sta	KJFK_22L_CAMRN_1.sta		
KJFK_22L_ALB_1DL.sta	KJFK_22L_ALB_1DL.sta		

```
EWR_VFR
#data/apt/KJFK/sids
KJFK_13R_DIXIE.sid
KJFK_13R_WAVEY_1.sid
KJFK_13R_SHIPP_1.sid
KJFK_13R_MERIT_1.sid
KJFK_13R_HAPIE_1.sid
KJFK_13R_GREKI_1.sid
KJFK_13R_DIXIE_1.sid
KJFK_13R_COATE_1.sid
KJFK_13R_BETTE_1.sid
KJFK_13R_BAYYS_1.sid
KJFK_13R_ACK_1.sid
KJFK_13L_WHITE_1.sid
KJFK_13L_WAVEY_1.sid
KJFK_13L_SHIPP_1.sid
KJFK_13L_RBV_1.sid
KJFK_13L_MERIT_1.sid
KJFK_13L_HAPIE_1.sid
KJFK_13L_GREKI_1.sid
KJFK_13L_DIXIE_1.sid
KJFK_13L_COATE_1.sid
KJFK_13L_BETTE_1.sid
KJFK_13L_BAYYS_1.sid
#data/apt/KJFK/usage
KJFK_VFR.usg
```

```
EWR_VFR_CTR
#data/apt/KJFK/sids
KJFK_13R_DIXIE.sid
KJFK_13R_WAVEY_1.sid
KJFK_13R_SHIPP_1.sid
KJFK_13R_MERIT_1.sid
KJFK_13R_HAPIE_1.sid
KJFK_13R_GREKI_1.sid
KJFK_13R_DIXIE_1.sid
KJFK_13R_COATE_1.sid
KJFK_13R_BETTE_1.sid
KJFK_13R_BAYYS_1.sid
KJFK_13R_ACK_1.sid
KJFK_13L_WHITE_1.sid
KJFK_13L_WAVEY_1.sid
KJFK_13L_SHIPP_1.sid
KJFK_13L_RBV_1.sid
KJFK_13L_MERIT_1.sid
KJFK_13L_HAPIE_1.sid
KJFK_13L_GREKI_1.sid
KJFK_13L_DIXIE_1.sid
KJFK_13L_COATE_1.sid
KJFK_13L_BETTE_1.sid
KJFK_13L_BAYYS_1.sid
#data/apt/KJFK/usage
KJFK_VFR.usg
```

```
EWR_IFR
#data/apt/KJFK/sids
KJFK_22R_WAVEY_1.sid
KJFK_22R_SHIPP_1.sid
KJFK_22R_RBV_1.sid
KJFK_22R_MERIT_1.sid
KJFK_22R_HAPIE_1.sid
KJFK_22R_GREKI_1.sid
KJFK_22R_DIXIE_1.sid
KJFK_22R_COATE_1.sid
KJFK_22R_BETTE_1.sid
KJFK_22R_BAYYS_1.sid
#data/apt/KJFK/usage
KJFK_IFR.usg
```

```
EWR_IFR_CTR
#data/apt/KJFK/sids
KJFK_22R_WAVEY_1.sid
KJFK_22R_SHIPP_1.sid
KJFK_22R_RBV_1.sid
KJFK_22R_MERIT_1.sid
KJFK_22R_HAPIE_1.sid
KJFK_22R_GREKI_1.sid
KJFK_22R_DIXIE_1.sid
KJFK_22R_COATE_1.sid
KJFK_22R_BETTE_1.sid
KJFK_22R_BAYYS_1.sid
#data/apt/KJFK/usage
KJFK_IFR.usg
```

```
EWR_VFR
#data/apt/KEWR/layouts
kewr.pol
#data/apt/KEWR/stars
KEWR_22L_WEARD_1.sta
KEWR_22L_WARRD_1.sta
KEWR_22L_SWANN_2.sta
KEWR_22L_SLT_1.sta
KEWR_22L_SAX_1.sta
KEWR_22L_PENNS_1.sta
KEWR_22L_PALEO_1.sta
KEWR_22L_METRO_1.sta
KEWR_22L_LOUIE_1.sta
KEWR_22L_HNK_1.sta
KEWR_22L_HFD_2.sta
KEWR_22L_HELON_1.sta
KEWR_22L_GEE_1.sta
KEWR_22L_FQM_2.sta
KEWR_22L_EXTOL_1.sta
KEWR_22L_ENO_1.sta
KEWR_22L_DAVYS_1.sta
KEWR_22L_AVP_1.sta
KEWR_22L_AGARD_1.sta
KEWR_11_WEARD_1.sta
KEWR_11_SWANN_1.sta
KEWR_11_SLT_1.sta
KEWR_11_SBJ_1.sta
KEWR_11_SAVVY_1.sta
KEWR_11_PXT_1.sta
KEWR_11_PENNS_1.sta
KEWR_11_LOUIE_1.sta
KEWR_11_HFD_1.sta
KEWR_11_HELON_1.sta
KEWR_11_GEE_1.sta
KEWR_11_FQM_1.sta
KEWR_11_EXTOL_2.sta
KEWR_11_DQO_1.sta
KEWR_11_DAVYS_1.sta
KEWR_11_AVP_1.sta
KEWR_11_AGARD_1.sta
```

```
EWR_VFR_CTR
#data/apt/KEWR/layouts
kewr_ctr.pol
#data/apt/KEWR/stars
KEWR_22L_WEARD_1.sta
KEWR_22L_WARRD_1.sta
KEWR_22L_SWANN_2.sta
KEWR_22L_SLT_1.sta
KEWR_22L_SAX_1.sta
KEWR_22L_PENNS_1.sta
KEWR_22L_PALEO_1.sta
KEWR_22L_METRO_1.sta
KEWR_22L_LOUIE_1.sta
KEWR_22L_HNK_1.sta
KEWR_22L_HFD_2.sta
KEWR_22L_HELON_1.sta
KEWR_22L_GEE_1.sta
KEWR_22L_FQM_2.sta
KEWR_22L_EXTOL_1.sta
KEWR_22L_ENO_1.sta
KEWR_22L_DAVYS_1.sta
KEWR_22L_AVP_1.sta
KEWR_22L_AGARD_1.sta
KEWR_11_WEARD_1.sta
KEWR_11_SWANN_1.sta
KEWR_11_SLT_1.sta
KEWR_11_SBJ_1.sta
KEWR_11_SAVVY_1.sta
KEWR_11_PXT_1.sta
KEWR_11_PENNS_1.sta
KEWR_11_LOUIE_1.sta
KEWR_11_HFD_1.sta
KEWR_11_HELON_1.sta
KEWR_11_GEE_1.sta
KEWR_11_FQM_1.sta
KEWR_11_EXTOL_2.sta
KEWR_11_DQO_1.sta
KEWR_11_DAVYS_1.sta
KEWR_11_AVP_1.sta
KEWR_11_AGARD_1.sta
```

```
EWR_IFR
#data/apt/KEWR/layouts
kewr.pol
#data/apt/KEWR/stars
KEWR_22L_WEARD_2IFR.sta
KEWR_22L_LOUIE_2IFR.sta
KEWR_22L_EXTOL_2IFR.sta
KEWR_22L_DAVYS_2IFR.sta
KEWR_22L_AGARD_2IFR.sta
KEWR_22L_WEARD_1IFR.sta
KEWR_22L_WARRD_1IFR.sta
KEWR_22L_SWANN_2IFR.sta
KEWR_22L_SLT_1IFR.sta
KEWR_22L_SAX_1IFR.sta
KEWR_22L_PENNS_1IFR.sta
KEWR_22L_PALEO_1IFR.sta
KEWR_22L_METRO_1IFR.sta
KEWR_22L_LOUIE_1IFR.sta
KEWR_22L_HNK_1IFR.sta
KEWR_22L_HFD_2IFR.sta
KEWR_22L_HELON_1IFR.sta
KEWR_22L_GEE_1IFR.sta
KEWR_22L_FQM_2IFR.sta
KEWR_22L_EXTOL_1IFR.sta
KEWR_22L_ENO_1IFR.sta
KEWR_22L_DAVYS_1IFR.sta
KEWR_22L_AVP_1IFR.sta
KEWR_22L_AGARD_1IFR.sta
```

```
EWR_IFR_CTR
#data/apt/KEWR/layouts
kewr_ctr.pol
#data/apt/KEWR/stars
KEWR_22L_WEARD_2IFR.sta
KEWR_22L_LOUIE_2IFR.sta
KEWR_22L_EXTOL_2IFR.sta
KEWR_22L_DAVYS_2IFR.sta
KEWR_22L_AGARD_2IFR.sta
KEWR_22L_WEARD_1IFR.sta
KEWR_22L_WARRD_1IFR.sta
KEWR_22L_SWANN_2IFR.sta
KEWR_22L_SLT_1IFR.sta
KEWR_22L_SAX_1IFR.sta
KEWR_22L_PENNS_1IFR.sta
KEWR_22L_PALEO_1IFR.sta
KEWR_22L_METRO_1IFR.sta
KEWR_22L_LOUIE_1IFR.sta
KEWR_22L_HNK_1IFR.sta
KEWR_22L_HFD_2IFR.sta
KEWR_22L_HELON_1IFR.sta
KEWR_22L_GEE_1IFR.sta
KEWR_22L_FQM_2IFR.sta
KEWR_22L_EXTOL_1IFR.sta
KEWR_22L_ENO_1IFR.sta
KEWR_22L_DAVYS_1IFR.sta
KEWR_22L_AVP_1IFR.sta
KEWR_22L_AGARD_1IFR.sta
KEWR_23_AGARD_1.sta
KEWR_23_AVP_1.sta
KEWR_23_DAVYS_1.sta
KEWR_23_ENO_1.sta
KEWR_23_EXTOL_1.sta
KEWR_23_FQM_1.sta
KEWR_23_GEE_1.sta
KEWR_23_HELON_1.sta
KEWR_23_HFD_1.sta
KEWR_23_HNK_1.sta
KEWR_23_LOUIE_1.sta
KEWR_23_METRO_1.sta
```

EWR_VFR	EWR_VFR_CTR	EWR_IFR	EWR_IFR_CTR
			KEWR_23_PALEO_1.sta KEWR_23_PENNS_1.sta KEWR_23_SAX_1.sta KEWR_23_SLT_1.sta KEWR_23_SWANN_1.sta KEWR_23_WARRD_1.sta KEWR_23_WEARD_1.sta

```
EWR_VFR
#data/apt/KEWR/sids
KEWR_22R_WHITE_2.sid
KEWR_22R_SBJ_2.sid
KEWR_22R_SAX_2.sid
KEWR_22R_PARKE_2.sid
KEWR_22R_NEION_2.sid
KEWR_22R_MERIT_2.sid
KEWR_22R_LANNA_2.sid
KEWR_22R_LANNA_1.sid
KEWR_22R_GREKI_2.sid
KEWR_22R_GREKI_1.sid
KEWR_22R_GAYEL_2.sid
KEWR_22R_GAYEL_1.sid
KEWR_22R_ETX_1.sid
KEWR_22R_ELIOT_2.sid
KEWR_22R_ELIOT_1.sid
KEWR_22R_DPK_1.sid
KEWR_22R_DIXIE_1.sid
KEWR_22R_CYN_1.sid
KEWR_22R_COATE_1.sid
KEWR_22R_BIGGY_2.sid
KEWR_22R_BAYYS_1.sid
KEWR_29_BAYYS_1.sid
KEWR_29_BIGGY_1.sid
KEWR_29_COATE_1.sid
KEWR_29_DIXIE_1.sid
KEWR_29_ELIOT_1.sid
KEWR_29_GAYEL_1.sid
KEWR_29_GREKI_1.sid
KEWR_29_LANNA_1.sid
KEWR_29_MERIT_1.sid
KEWR_29_NEION_1.sid
KEWR_29_PARKE_1.sid
KEWR_29_SAX_1.sid
KEWR_29_SBJ_1.sid
KEWR_29_WHITE_1.sid
#data/apt/KEWR/usage
KEWR_VFR.usg
```

```
EWR_VFR_CTR
#data/apt/KEWR/sids
KEWR_22R_WHITE_2.sid
KEWR_22R_SBJ_2.sid
KEWR_22R_SAX_2.sid
KEWR_22R_PARKE_2.sid
KEWR_22R_NEION_2.sid
KEWR_22R_MERIT_2.sid
KEWR_22R_LANNA_2.sid
KEWR_22R_LANNA_1.sid
KEWR_22R_GREKI_2.sid
KEWR_22R_GREKI_1.sid
KEWR_22R_GAYEL_2.sid
KEWR_22R_GAYEL_1.sid
KEWR_22R_ETX_1.sid
KEWR_22R_ELIOT_2.sid
KEWR_22R_ELIOT_1.sid
KEWR_22R_DPK_1.sid
KEWR_22R_DIXIE_1.sid
KEWR_22R_CYN_1.sid
KEWR_22R_COATE_1.sid
KEWR_22R_BIGGY_2.sid
KEWR_22R_BAYYS_1.sid
KEWR_29_BAYYS_1.sid
KEWR_29_BIGGY_1.sid
KEWR_29_COATE_1.sid
KEWR_29_DIXIE_1.sid
KEWR_29_ELIOT_1.sid
KEWR_29_GAYEL_1.sid
KEWR_29_GREKI_1.sid
KEWR_29_LANNA_1.sid
KEWR_29_MERIT_1.sid
KEWR_29_NEION_1.sid
KEWR_29_PARKE_1.sid
KEWR_29_SAX_1.sid
KEWR_29_SBJ_1.sid
KEWR_29_WHITE_1.sid
#data/apt/KEWR/usage
KEWR_VFR_CTR.usg
```

```
EWR_IFR
#data/apt/KEWR/sids
KEWR_22R_BAYYS_2.sid
KEWR_22R_WHITE_2.sid
KEWR_22R_SBJ_2.sid
KEWR_22R_SAX_2.sid
KEWR_22R_PARKE_2.sid
KEWR_22R_NEION_2.sid
KEWR_22R_MERIT_2.sid
KEWR_22R_LANNA_2.sid
KEWR_22R_LANNA_1.sid
KEWR_22R_GREKI_2.sid
KEWR_22R_GREKI_1.sid
KEWR_22R_GAYEL_2.sid
KEWR_22R_GAYEL_1.sid
KEWR_22R_ETX_1.sid
KEWR_22R_ELIOT_2.sid
KEWR_22R_ELIOT_1.sid
KEWR_22R_DPK_1.sid
KEWR_22R_DIXIE_1.sid
KEWR_22R_CYN_1.sid
KEWR_22R_COATE_1.sid
KEWR_22R_BIGGY_2.sid
#data/apt/KEWR/usage
KEWR_IFR.usg
```

```
EWR_IFR_CTR
#data/apt/KEWR/sids
KEWR_22R_BAYYS_2.sid
KEWR_22R_WHITE_2.sid
KEWR_22R_SBJ_2.sid
KEWR_22R_SAX_2.sid
KEWR_22R_PARKE_2.sid
KEWR_22R_NEION_2.sid
KEWR_22R_MERIT_2.sid
KEWR_22R_LANNA_2.sid
KEWR_22R_LANNA_1.sid
KEWR_22R_GREKI_2.sid
KEWR_22R_GREKI_1.sid
KEWR_22R_GAYEL_2.sid
KEWR_22R_GAYEL_1.sid
KEWR_22R_ETX_1.sid
KEWR_22R_ELIOT_2.sid
KEWR_22R_ELIOT_1.sid
KEWR_22R_DPK_1.sid
KEWR_22R_DIXIE_1.sid
KEWR_22R_CYN_1.sid
KEWR_22R_COATE_1.sid
KEWR_22R_BIGGY_2.sid
KEWR_23_BAYYS_1.sid
KEWR_23_BIGGY_1.sid
KEWR_23_COATE_1.sid
KEWR_23_DIXIE_1.sid
KEWR_23_CYN_1.sid
KEWR_23_ELIOT_1.sid
KEWR_23_GAYEL_1.sid
KEWR_23_GREKI_1.sid
KEWR_23_LANNA_1.sid
KEWR_23_MERIT_1.sid
KEWR_23_NEION_1.sid
KEWR_23_PARKE_1.sid
KEWR_23_SAX_1.sid
KEWR_23_SBJ_1.sid
KEWR_23_WHITE_1.sid
#data/apt/KEWR/usage
KEWR_IFR_CTR.usg
```

iad_for_NASA_VFR	**iad_CTR_VFR**	**iad_for_NASA_IFR**	**iad_CTR_IFR**
# single_terminal	# single_terminal	# single_terminal	# single_terminal
#data/map/gtool	#data/map/gtool	#data/map/gtool	#data/map/gtool
globe_new.pol	globe_new.pol	globe_new.pol	globe_new.pol
zdcsecs.pol	zdcsecs.pol	zdcsecs.pol	zdcsecs.pol
zbwsecs.pol	zbwsecs.pol	zbwsecs.pol	zbwsecs.pol
znysecs.pol	znysecs.pol	znysecs.pol	znysecs.pol
#data/map/3d	#data/map/3d	#data/map/3d	#data/map/3d
#data/wpt	#data/wpt	#data/wpt	#data/wpt
master.WPT	master.WPT	master.WPT	master.WPT
#data/apt	#data/apt	#data/apt	#data/apt
master.APT	master.APT	master.APT	master.APT
#data/rts	#data/rts	#data/rts	#data/rts
BASE_00_edit1.RTS	BASE_00_edit1.RTS	BASE_00_edit1.RTS	BASE_00_edit1.RTS
#data/acf	#data/acf	#data/acf	#data/acf
BASE_00_KIAD.ACF	wdc_ctr_practic.ACF	BASE_00_KIAD.ACF	wdc_ctr_practic.ACF
NB Runway Usage	NB Runway Usage	NB Runway Usage	NB Runway Usage
KIAD	KIAD	KIAD	KIAD
01R J arr	01R J arr	01R J,T arr	01R J,T arr
01L T arr, J dep	01L T arr, J dep	01L J,T dep	01L J,T dep
30 T dep	30 T dep		02 CTR arr & dep
KDCA	KDCA	KDCA	KDCA
36 J,T arr & dep	36 J,T arr & dep	36 J,T arr & dep	36 J,T arr & dep
33 T arr	33 T arr		
03 T dep	03 T dep	03 T dep	03 T dep
KBWI	KBWI	KBWI	KBWI
28 J,T dep	28 J,T dep	28 J,T dep	28 J,T dep
33L J,T arr	33L J,T arr	33L J,T arr	33L J,T arr
33R T arr & dep	33R T arr & dep	33R T arr & dep	33R T arr & dep

```
IAD_VFR

data/apt/KBWI/layouts
KBWI.pol
#data/apt/KBWI/sids
KBWI_33R_ACY_1.sid
KBWI_33R_AGARD_1.sid
KBWI_33R_BUFFR_1.sid
KBWI_33R_DAILY_1.sid
KBWI_33R_DQO_1.sid
KBWI_33R_DQO_2.sid
KBWI_33R_EMI_1.sid
KBWI_33R_ENO_1.sid
KBWI_33R_JERES_1.sid
KBWI_33R_MRB_1.sid
KBWI_33R_OOD_1.sid
KBWI_33R_PALEO_1.sid
KBWI_33R_PXT_1.sid
KBWI_33R_SIE_1.sid
KBWI_28_ACY_1.sid
KBWI_28_ACY_2.sid
KBWI_28_AGARD_1.sid
KBWI_28_BUFFR_1.sid
KBWI_28_DAILY_1.sid
KBWI_28_EMI_1.sid
KBWI_28_ENO_1.sid
KBWI_28_ENO_2.sid
KBWI_28_DQO_1.sid
KBWI_28_FLUKY_1.sid
KBWI_28_JERES_1.sid
KBWI_28_MRB_1.sid
KBWI_28_PALEO_1.sid
KBWI_28_PALEO_2.sid
KBWI_28_OOD_1.sid
KBWI_28_OOD_2.sid
KBWI_28_SIE_1.sid
KBWI_28_SIE_2.sid
```

```
IAD_VFR_CTR

data/apt/KBWI/layouts
KBWI.pol
#data/apt/KBWI/sids
KBWI_33R_ACY_1.sid
KBWI_33R_AGARD_1.sid
KBWI_33R_BUFFR_1.sid
KBWI_33R_DAILY_1.sid
KBWI_33R_DQO_1.sid
KBWI_33R_DQO_2.sid
KBWI_33R_EMI_1.sid
KBWI_33R_ENO_1.sid
KBWI_33R_JERES_1.sid
KBWI_33R_MRB_1.sid
KBWI_33R_OOD_1.sid
KBWI_33R_PALEO_1.sid
KBWI_33R_PXT_1.sid
KBWI_33R_SIE_1.sid
KBWI_28_ACY_1.sid
KBWI_28_ACY_2.sid
KBWI_28_AGARD_1.sid
KBWI_28_BUFFR_1.sid
KBWI_28_DAILY_1.sid
KBWI_28_EMI_1.sid
KBWI_28_ENO_1.sid
KBWI_28_ENO_2.sid
KBWI_28_DQO_1.sid
KBWI_28_FLUKY_1.sid
KBWI_28_JERES_1.sid
KBWI_28_MRB_1.sid
KBWI_28_PALEO_1.sid
KBWI_28_PALEO_2.sid
KBWI_28_OOD_1.sid
KBWI_28_OOD_2.sid
KBWI_28_SIE_1.sid
KBWI_28_SIE_2.sid
```

```
IAD_IFR

#data/apt/KBWI/layouts
KBWI.pol
#data/apt/KBWI/sids
KBWI_33R_AGARD_1.sid
KBWI_33R_ACY_1.sid
KBWI_33R_BUFFR_1.sid
KBWI_33R_DAILY_1.sid
KBWI_33R_DQO_1.sid
KBWI_33R_EMI_1.sid
KBWI_33R_ENO_1.sid
KBWI_33R_JERES_1.sid
KBWI_33R_MRB_1.sid
KBWI_33R_OOD_1.sid
KBWI_33R_PALEO_1.sid
KBWI_33R_PXT_1.sid
KBWI_33R_SIE_1.sid
KBWI_28_AGARD_1.sid
KBWI_28_ACY_1.sid
KBWI_28_ACY_2.sid
KBWI_28_BUFFR_1.sid
KBWI_28_DAILY_1.sid
KBWI_28_DQO_1.sid
KBWI_28_EMI_1.sid
KBWI_28_ENO_1.sid
KBWI_28_ENO_2.sid
KBWI_28_FLUKY_1.sid
KBWI_28_JERES_1.sid
KBWI_28_MRB_1.sid
KBWI_28_OOD_1.sid
KBWI_28_OOD_2.sid
KBWI_28_PALEO_1.sid
KBWI_28_PALEO_2.sid
KBWI_28_SIE_1.sid
KBWI_28_SIE_2.sid
```

```
IAD_IFR_CTR

#data/apt/KBWI/layouts
KBWI.pol
#data/apt/KBWI/sids
KBWI_33R_AGARD_1.sid
KBWI_33R_ACY_1.sid
KBWI_33R_BUFFR_1.sid
KBWI_33R_DAILY_1.sid
KBWI_33R_DQO_1.sid
KBWI_33R_EMI_1.sid
KBWI_33R_ENO_1.sid
KBWI_33R_JERES_1.sid
KBWI_33R_MRB_1.sid
KBWI_33R_OOD_1.sid
KBWI_33R_PALEO_1.sid
KBWI_33R_PXT_1.sid
KBWI_33R_SIE_1.sid
KBWI_28_AGARD_1.sid
KBWI_28_ACY_1.sid
KBWI_28_ACY_2.sid
KBWI_28_BUFFR_1.sid
KBWI_28_DAILY_1.sid
KBWI_28_DQO_1.sid
KBWI_28_EMI_1.sid
KBWI_28_ENO_1.sid
KBWI_28_ENO_2.sid
KBWI_28_FLUKY_1.sid
KBWI_28_JERES_1.sid
KBWI_28_MRB_1.sid
KBWI_28_OOD_1.sid
KBWI_28_OOD_2.sid
KBWI_28_PALEO_1.sid
KBWI_28_PALEO_2.sid
KBWI_28_SIE_1.sid
KBWI_28_SIE_2.sid
```

IAD_VFR	IAD_VFR_CTR	IAD_IFR	IAD_IFR_CTR
#data/apt/KBWI/stars	#data/apt/KBWI/stars	#data/apt/KBWI/stars	#data/apt/KBWI/stars
KBWI_33R_AML_1.sta	KBWI_33R_AML_1.sta	KBWI_33R_AML_1.sta	KBWI_33R_AML_1.sta
KBWI_33R_EMI_1.sta	KBWI_33R_EMI_1.sta	KBWI_33R_EMI_1IFR.sta	KBWI_33R_EMI_1IFR.sta
KBWI_33R_ENO_1.sta	KBWI_33R_ENO_1.sta	KBWI_33R_ENO_2IFR.sta	KBWI_33R_ENO_2IFR.sta
KBWI_33R_GRACO_1.sta	KBWI_33R_GRACO_1.sta	KBWI_33R_GRACO_1.sta	KBWI_33R_GRACO_1.sta
KBWI_33R_PXT_1.sta	KBWI_33R_PXT_1.sta	KBWI_33R_PXT_2IFR.sta	KBWI_33R_PXT_2IFR.sta
KBWI_33R_SBY_1.sta	KBWI_33R_SBY_1.sta	KBWI_33L_BELAY_1.sta	KBWI_33L_BELAY_1.sta
KBWI_33L_BELAY_1.sta	KBWI_33L_BELAY_1.sta	KBWI_33L_BILIT_1.sta	KBWI_33L_BILIT_1.sta
KBWI_33L_BILIT_1.sta	KBWI_33L_BILIT_1.sta	KBWI_33L_BILIT_2IF.sta	KBWI_33L_BILIT_2IF.sta
KBWI_33L_CSN_1.sta	KBWI_33L_CSN_1.sta	KBWI_33L_CSN_2IFR.sta	KBWI_33L_CSN_2IFR.sta
KBWI_33L_EMI_1.sta	KBWI_33L_EMI_1.sta	KBWI_33L_EMI_2IFR.sta	KBWI_33L_EMI_2IFR.sta
KBWI_33L_GRACO_1.sta	KBWI_33L_GRACO_1.sta	KBWI_33L_GRACO_1.sta	KBWI_33L_GRACO_1.sta
KBWI_33L_MXE_2.sta	KBWI_33L_MXE_2.sta	KBWI_33L_MXE_4IFR.sta	KBWI_33L_MXE_4IFR.sta
KBWI_33L_MXE_1.sta	KBWI_33L_MXE_1.sta	KBWI_33L_MXE_3IFR.sta	KBWI_33L_MXE_3IFR.sta
KBWI_33L_OTT_1.sta	KBWI_33L_OTT_1.sta	KBWI_33L_OTT_2IFR.sta	KBWI_33L_OTT_2IFR.sta
KBWI_33L_RIC_1.sta	KBWI_33L_RIC_1.sta	KBWI_33L_RIC_1.sta	KBWI_33L_RIC_1.sta
#data/apt/KBWI/usage	#data/apt/KBWI/usage	#data/apt/KBWI/usage	#data/apt/KBWI/usage
KBWI_VFR.usg	KBWI_VFR.usg	KBWI_IFR.usg	KBWI_IFR.usg

```
IAD_VFR

#data/apt/KDCA/layouts
KDCA.pol
#data/apt/KDCA/sids
KDCA_36_ENO_1.sid
KDCA_36_GTN_1.sid
KDCA_36_OOD_1.sid
KDCA_36_PALEO_1.sid
KDCA_36_PXT_1.sid
KDCA_36_SWANN_1.sid
KDCA_03_ENO_1.sid
KDCA_03_OOD_1.sid
KDCA_03_GTN_1.sid
KDCA_03_PALEO_1.sid
KDCA_03_PXT_1.sid
KDCA_03_SWANN_1.sid

#data/apt/KDCA/stars
KDCA_36_BAL_1.sta
KDCA_36_BAL_2.sta
KDCA_36_BKW_1.sta
KDCA_36_BUCKO_1.sta
KDCA_36_CSN_1.sta
KDCA_36_ESL_1.sta
KDCA_36_FAK_1.sta
KDCA_36_HVQ_1.sta
KDCA_36_OTT_1.sta
KDCA_36_OTT_2.sta
KDCA_36_RIC_1.sta
KDCA_03_CSN_1.sta
KDCA_33_BAL_1.sta
KDCA_33_CSN_1.sta
KDCA_33_EMI_1.sta
KDCA_33_OTT_1.sta
KDCA_33_RIC_1.sta
#data/apt/KDCA/usage
KDCA_VFR.usg
```

```
IAD_VFR_CTR

#data/apt/KDCA/layouts
KDCA.pol
#data/apt/KDCA/sids
KDCA_36_ENO_1.sid
KDCA_36_GTN_1.sid
KDCA_36_OOD_1.sid
KDCA_36_PALEO_1.sid
KDCA_36_PXT_1.sid
KDCA_36_SWANN_1.sid
KDCA_03_ENO_1.sid
KDCA_03_OOD_1.sid
KDCA_03_GTN_1.sid
KDCA_03_PALEO_1.sid
KDCA_03_PXT_1.sid
KDCA_03_SWANN_1.sid

#data/apt/KDCA/stars
KDCA_36_BAL_1.sta
KDCA_36_BAL_2.sta
KDCA_36_BKW_1.sta
KDCA_36_BUCKO_1.sta
KDCA_36_CSN_1.sta
KDCA_36_ESL_1.sta
KDCA_36_FAK_1.sta
KDCA_36_HVQ_1.sta
KDCA_36_OTT_1.sta
KDCA_36_OTT_2.sta
KDCA_36_RIC_1.sta
KDCA_03_CSN_1.sta
KDCA_33_BAL_1.sta
KDCA_33_CSN_1.sta
KDCA_33_EMI_1.sta
KDCA_33_OTT_1.sta
KDCA_33_RIC_1.sta
#data/apt/KDCA/usage
KDCA_VFR.usg
```

```
IAD_IFR

#data/apt/KDCA/layouts
KDCA.pol
#data/apt/KDCA/sids
KDCA_36_ENO_2IFR.sid
KDCA_36_GTN_1.sid
KDCA_36_OOD_2IFR.sid
KDCA_36_PALEO_2IFR.sid
KDCA_36_PXT_1.sid
KDCA_36_SWANN_2IFR.sid
KDCA_03_ENO_2IFR.sid
KDCA_03_GTN_1.sid
KDCA_03_OOD_2IFR.sid
KDCA_03_PALEO_2IFR.sid
KDCA_03_PXT_1.sid
KDCA_03_SWANN_2IFR.sid

#data/apt/KDCA/stars
KDCA_36_BAL_2IFR.sta
KDCA_36_BUCKO_2IFR.sta
KDCA_36_BKW_2IFR.sta
KDCA_36_CSN_2IFR.sta
KDCA_36_ESL_2IFR.sta
KDCA_36_FAK_2IFR.sta
KDCA_36_HVQ_2IFR.sta
KDCA_36_OTT_1ILS.sta
KDCA_36_RIC_2IFR.sta
#data/apt/KDCA/usage
KDCA_IFR.usg
```

```
IAD_IFR_CTR

#data/apt/KDCA/layouts
KDCA.pol
#data/apt/KDCA/sids
KDCA_36_ENO_2IFR.sid
KDCA_36_GTN_1.sid
KDCA_36_OOD_2IFR.sid
KDCA_36_PALEO_2IFR.sid
KDCA_36_PXT_1.sid
KDCA_36_SWANN_2IFR.sid
KDCA_03_ENO_2IFR.sid
KDCA_03_GTN_1.sid
KDCA_03_OOD_2IFR.sid
KDCA_03_PALEO_2IFR.sid
KDCA_03_PXT_1.sid
KDCA_03_SWANN_2IFR.sid

#data/apt/KDCA/stars
KDCA_36_BAL_2IFR.sta
KDCA_36_BUCKO_2IFR.sta
KDCA_36_BKW_2IFR.sta
KDCA_36_CSN_2IFR.sta
KDCA_36_ESL_2IFR.sta
KDCA_36_FAK_2IFR.sta
KDCA_36_HVQ_2IFR.sta
KDCA_36_OTT_1ILS.sta
KDCA_36_RIC_2IFR.sta
#data/apt/KDCA/usage
KDCA_IFR.usg
```

```
IAD_VFR

#data/apt/KIAD/layouts
KIAD.pol
#data/apt/KIAD/stars
KIAD_01R_BAL_1.sta
KIAD_01R_BARIN_1.sta
KIAD_01R_COATT_2.sta
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KIAD_01R_DOCCS_1.sta
KIAD_01R_EMI_1.sta
KIAD_01R_ESL_1.sta
KIAD_01R_JASEN_1.sta
KIAD_01R_KROLL_1.sta
KIAD_01R_OTT_1.sta
KIAD_01R_POT113_1.sta
KIAD_01R_PXT_1.sta
KIAD_01R_ROBRT_1.sta
KIAD_01R_ROBRT_2.sta
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KIAD_01L_COATT_1.sta
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KIAD_01L_KROLL_1.sta
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KIAD_01R_JASEN_1.sta
KIAD_01R_KROLL_1.sta
KIAD_01R_OTT_1.sta
KIAD_01R_POT113_1.sta
KIAD_01R_PXT_1.sta
KIAD_01R_ROBRT_1.sta
KIAD_01R_ROBRT_2.sta
KIAD_01L_COATT_2.sta
KIAD_01L_COATT_1.sta
KIAD_01L_CSN_3.sta
KIAD_01L_DOCCS_6.sta
KIAD_01L_DOCCS_5.sta
KIAD_01L_ESL_8.sta
KIAD_01L_ESL_7.sta
KIAD_01L_HGR_1.sta
KIAD_01L_JASEN_1.sta
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KIAD_01L_MRB_1.sta
KIAD_01L_ROBRT_1.sta
```

```
IAD_IFR

#data/apt/KIAD/layouts
KIAD.pol
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KIAD_01R_CSN_2IFR.sta
KIAD_01R_DOCCS_2IF.sta
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KIAD_01R_JASEN_2IF.sta
KIAD_01R_KROLL_1IF.sta
KIAD_01R_OTT_1IFR.sta
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IAD_IFR_CTR

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KIAD_01R_COATT_2IF.sta
KIAD_01R_CSN_2IFR.sta
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KIAD_01R_ESL_2IFR.sta
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KIAD_01R_OTT_1IFR.sta
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KIAD_01R_ROBRT_2IFR.sta
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KIAD_01L_DOCCS_5.sta
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KIAD_30_HANEY_2.sid
KIAD_30_HGR_1.sid
KIAD_30_JERES_1.sid
KIAD_30_JERES_2.sid
KIAD_30_LDN_1.sid
KIAD_30_MRB_1.sid
KIAD_30_PALEO_1.sid
KIAD_30_SWANN_1.sid
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KIAD_01L_BUFFR_1.sid
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KIAD_01L_OTT_1.sid
KIAD_01L_PALEO_1.sid
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KIAD_01L_SWANN_4.sid
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KIAD_VFR.usg
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IAD_VFR_CTR
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KIAD_30_CSN_2.sid
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KIAD_01L_MRB_1.sid
KIAD_01L_OTT_1.sid
KIAD_01L_PALEO_1.sid
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IAD_IFR
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KIAD_01L_OTT_1.sid
KIAD_01L_MRB_1.sid
KIAD_01L_JERES_2.sid
KIAD_01L_JERES_1.sid
KIAD_01L_HGR_1.sid
KIAD_01L_FILIX_1.sid
KIAD_01L_DAILY_2.sid
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#data/apt/KIAD/usage
KIAD_IFR.usg
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IAD_IFR_CTR
#data/apt/KIAD/sids
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KIAD_01L_BUFFR_2.sid
KIAD_01L_DAILY_2.sid
KIAD_01L_FILIX_1.sid
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KIAD_01L_HGR_1.sid
KIAD_01L_JERES_1.sid
KIAD_01L_JERES_2.sid
KIAD_01L_LDN_1.sid
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KIAD_01L_OTT_1.sid
KIAD_01L_PALEO_1.sid
KIAD_01L_POT133_2.sid
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KIAD_01L_SWANN_4.sid
KIAD_01L_WOOLY_2.sid
KIAD_02_AML271030_1.sid
KIAD_02_CSN_1.sid
KIAD_02_FILIX_1.sid
KIAD_02_FLUKY_1.sid
KIAD_02_HAFNR_1.sid
KIAD_02_JERES_1.sid
KIAD_02_LDN_1.sid
KIAD_02_MRB_1.sid
KIAD_02_OTT_1.sid
KIAD_02_PALEO_1.sid
KIAD_02_POT133_1.sid
KIAD_02_SWANN_1.sid
KIAD_02_WOOLY_1.sid
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KIAD_IFR_CTR.usg
```

Appendix C
CTR Noise Data File

```
"NEW_AC",1
"CTR","CURVE=250C30 PARAM=HELI STAGE 2=HORFLT CATEGORY=PGA","ALT3D"
"NOISE_CURVES",21
"NC 250C30 3 BY 8 3 BY 8"
"EPNL"
"THRUSTS 1 2 3"
"500 90.2 101.7 112.0"
"1000 85.8 98.26 105.8"
"1500 83.1 96.97 104"
"2250 79.4 95.2 102.1"
"3000 73.7 93.44 101.3"
"3850 67.6 92.51 100.5"
"4700 63.1 88.81 98.63"
"6000 56.8 86.46 94.72"
"SEL"
"THRUSTS 1 2 3"
"500 88.6 95.33 108.3"
"1000 84.2 91.71 101.3"
"1500 81.5 90.4 99.8"
"2250 77.8 88.7 98.3"
"3000 72.1 87.5 97.46"
"3850 66 85.5 96.64"
"4700 61.5 82.62 94.47"
"6000 55.2 80.82 90.58"
"APPR_PARAMS",1
"AP HELI WEIGHT=10000 ENGINE=2"
"PROFILE_APPR",5
"PF ALT3D SEGMENTS=7"
"DISTANCES 20 10 5 3 1 0 0"
"ALTITUDES 6000 3236 1644 1007 370 0 0"
"SPEEDS 180 180 180 180 180 180 32"
"THRUSTS 3 3 3 3 3 3"
"PROFILE_TAKEOFF",5
```

"PF HORFLT SEGMENTS=8 WEIGHT=10000 ENGINES=2"

"DISTANCES 0 1376 4126 6876 6877 9626 10000 15000"

"ALTITUDES 0 0 500 1000 1000 1500 1500 1500"

"SPEEDS 32 180 180 180 180 180 180 180"

"THRUSTS 2 2 2 2 1 1 1"

Appendix D
Abbreviations

ACIM	Air Carrier Investment Model
ASM	available seat miles
BWI	Baltimore-Washington International Airport, Baltimore, Maryland
CTR	Civil Tiltrotor
CTRDAC	Civil Tiltrotor Development Advisory Committee
DCA	Reagan National Airport, Washington, D.C.
EPNL	Effective Perceived Noise Levels
EWR	Newark International Airport, Newark, Ohio
FAA	Federal Aviation Administration
IAD	Dulles International Airport, Washington, D.C.
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JFK	John F. Kennedy International Airport, New York, New York
LMINET	A queuing network model of the U.S. National Airspace
NAS	National Airspace System
NASA	National Aeronautics and Space Administratoin
OAG	Official Airline Guide
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival Route
TAAM	Total Airport and Airspace Modeler
TRACON	Terminal Radar Approach Control

VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	VHF Omni Range

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13. ABSTRACT (*Maximum 200 words*)
NASA tasked LMI to assess the potential contributions of a yet-undeveloped Civil Tiltrotor aircraft (CTR) in improving capacity in the National Airspace System in all weather conditions. The CTRs studied have assumed operating parameters beyond current CTR capabilities. LMI analyzed CTRs three ways: in fast-time terminal area modeling simulations of New York and Washington to determine delay and throughput impacts; in the Integrated Noise Model, to determine local environmental impact; and with an economic model, to determine the price viability of a CTR. The fast-time models encompassed a 250 nmi range and included traffic interactions from local airports. Both the fast-time simulation and the noise model assessed impacts from traffic levels projected for 1999, 2007, and 2017. Results: CTRs can reduce terminal area delays due to concrete congestion in all time frames. The maximum effect, the ratio of CTRs to jets and turboprop aircraft at a subject airport should be optimized. The economic model considered US traffic only and forecasted CTR sales beginning in 2010.

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