Application of CNS/ATM Technologies to Airport Management

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Introduction

Air Traffic Control (ATC) is responsible for the safe and efficient movement of aircraft throughout the National Airspace System (NAS). While air traffic controllers manage traffic at the nation's larger airports, it is the responsibility of an airport's management to manage the airport business enterprise as a commercially viable operation. Many U.S. airports are operated as commercial enterprises, where the goal is for revenues to exceed costs thereby yielding profit. As improvements in technology have been introduced for ATC, commercial uses of these technologies have appealed to airport management, where there are potential applications to improve operational efficiencies and reduce operating costs.

Communication, Navigation, Surveillance/Air Traffic Management or CNS/ATM is the term given to a variety of technologies aimed at improving ATC and airline management. CNS/ATM systems are provided primarily for the use of ATC and airspace users, including commercial airlines. In this paper the use of ATC and airline technologies and derivate systems for airport management purposes are discussed. Examples are presented from deployed systems and field trials. This paper focuses on the techniques used to identify aircraft and to determine noise levels and emissions produced by each aircraft.

Aircraft Identification

Identification of all aircraft that use an airport is key to managing airport operations. If an airport can identify all users then the airport can manage a host of functions ranging from billing for landing fees, use of facilities, to facilities planning and overall master planning. To identify a specific airframe the airport needs to gain access to the tail number. Once the tail number of the aircraft is known the airport can access all of the registration data on a specific aircraft. There are basically four sources for acquiring aircraft tail numbers in U.S. airspace which are discussed below.

Visual Acquisition of Tail Number

The ***first tail number source*** is visual acquisition, where a person such as a Fixed-Base Operator staff member will manually enter the tail number into a spreadsheet for each and every aircraft arriving at and departing from the airport. As strange as it may seem there are airports in North America that use this manually intensive and error-prone approach. Over the past few years some companies have tried to implement camera systems to photograph tail numbers and then perform character recognition in order to automate the visual acquisition of tail number information. While this is a good theoretical idea it has proven very difficult to implement effectively at airports.

Mode S Acquisition of Tail Number

The ***second tail number source*** is automated and uses the aircraft's Mode S code to provide the tail number. There are 2^{24} available Mode S Numbers worldwide – which is a very large number – *much* larger than the number of aircraft. These numbers, which are encoded into an aircraft's transponder, are allocated in blocks to different countries by the International Civil Aviation Organization (ICAO). Every aircraft that has a Mode S transponder has a unique Mode S code allocated to its transponder. The assignment of a Mode S code is specific to an aircraft, much in the same way that a license plate is assigned to a car. Generally, every aircraft that has over 15 seats, or is over 30,000 lbs is required to use collision avoidance avionics in the U.S., which requires a Mode S transponder. Therefore, all air carriers, most business jets, and larger cargo aircraft have Mode S transponders on board.

It is very important to note, however, that the reason for the assignment of unique Mode S codes is not to make it easy for airport management to identify aircraft. The reason for the Mode S codes is to allow ATC radars to handle and sort out high numbers of aircraft in high density airspace. Back in the 1970s, the aerospace industry, working through ICAO, realized that the current system which allocated up to 4096 different Mode A beacon codes, would not handle air traffic growth and that high density airspace would experience multiple aircraft with the same beacon code at the same time. This could degrade the surveillance processing capability of terminal and en route radars and could result in potentially unsafe situations. Hence the introduction of selective addressing radar, or Mode S, where "S" stands for select. By doubling the number of transponder information bits from 12 to 24, ICAO went from 4096 re-usable codes to over 16 million unique permanent codes. ATC radars can use the Mode S codes to selectively address each and every equipped aircraft. Since every aircraft has a different code it is guaranteed that there will be no duplication of codes as seen by any radar at any location, worldwide. As the Mode S radar rotates it may interrogate each aircraft separately, unlike the older radars that interrogate all aircraft every rotation. The ATC radar and automation uses only the Mode S code and flight plan, and does not use aircraft registration information, as that is not necessary for air traffic controllers to provide surveillance or separation services for aircraft.

On the other hand, for airport management there is little interest in an aircraft's Mode S code, *per se*. The Mode S code is basically a stepping stone that allows access to the tail number, and then all the details on the airframe. However, it is more difficult than it might seem to convert any given Mode S code to a tail number. Some countries use an algorithm to convert the 24 bit Mode S number into the aircraft tail number. These countries include the U.S., Germany, and Australia. Most other countries do not use an algorithm but use a look-up table that correlates the Mode S code with the tail number. The beauty of the algorithm is that once obtained, all aircraft tail numbers can be decoded for that specific country of registration. Therefore, countries that use algorithms make it fairly easy with regard to airport management. For look-up tables, access is required to each and every Mode S – tail number correlation. While some countries make their look-up tables freely available, others do not publish the information, making it a challenge to access the information.

Figure 1 is an example of an aircraft tracked using a wide area multilateration system, where the position and track information is calculated with high accuracy and a high update of at least once per second. The Code "5635" is the aircraft's Mode A code, and the "N57" number is the unique U.S. registered tail number which was converted from the Mode S code in real time. Looking up the registration number in real time identifies that this particular aircraft is the FAA's Lear Jet 60 flight inspection aircraft.

Figure 2 is a bit busier, showing over-flights during a several hour period at an airport in the North East. The aircraft fly over a waypoint on a major air route in New England. By clicking on any of the tracks the user can look at aircraft identification information from the Mode S, decoded to tail number and then correlated with an aircraft registration database. The hypertext box on the left of the figure shows the information available which includes the registration number, and various details on the airframe including the types of engines.

<u>ACARS Acquisition of Tail Number</u>

The ***third tail number source*** is the Aircraft Communications Addressing and Reporting System (ACARS). Although the Mode S codes discussed above provide unique transponder codes for aircraft it is not necessarily straightforward to track Mode S codes to aircraft registration numbers. This is a problem generally for new U.S. aircraft, aircraft that have recently changed ownership, or foreign aircraft. Furthermore, in several trials the authors found that commercial aircraft databases incorrectly identified over 5% of all aircraft, due to changes in aircraft registration details that had not been updated for various reasons. In an attempt to fill in the blanks for non U.S. aircraft and aircraft that are incorrectly identified or missing from commercial databases the authors integrated a feed from the ACARS system. The ACARS system is used by the vast majority of all air carriers, and it is basically a form of electronic data transfer between aircraft and their operations centers. It is essentially an e- mail service for aircraft and provides a valuable

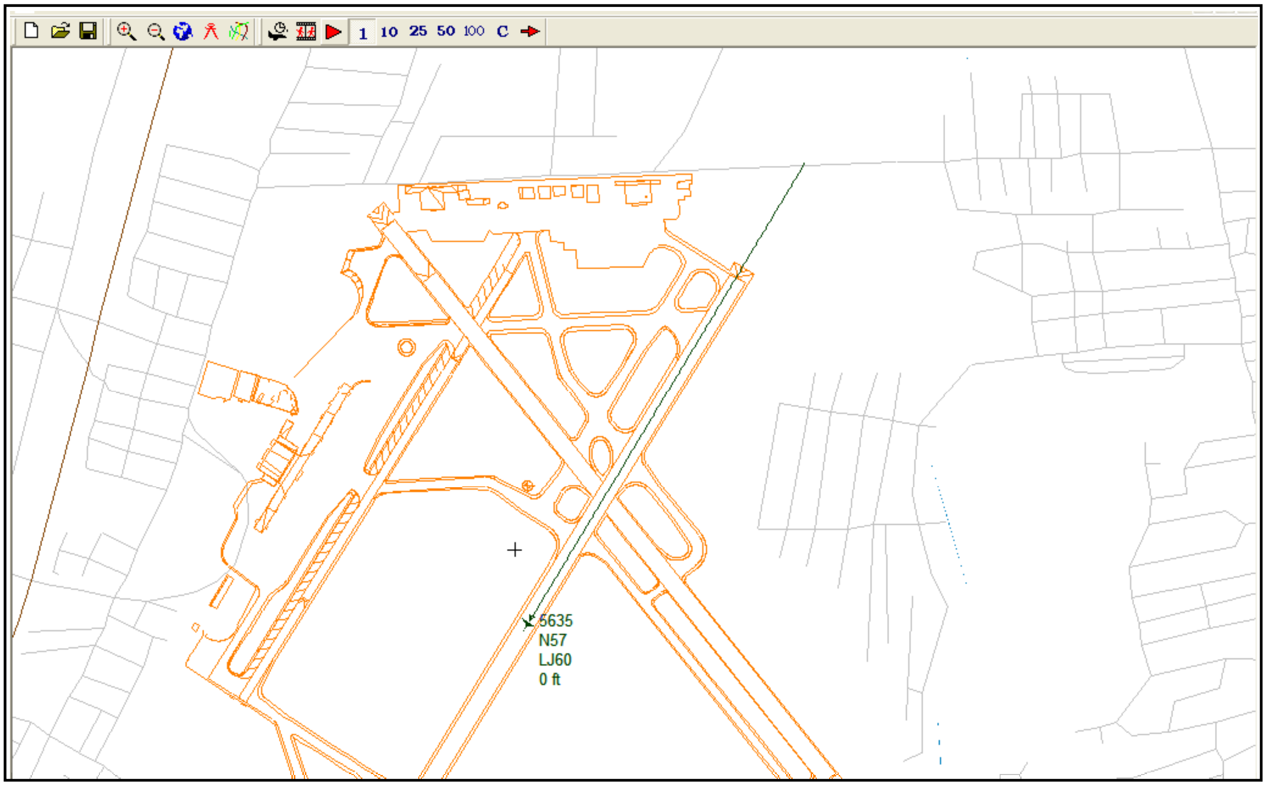
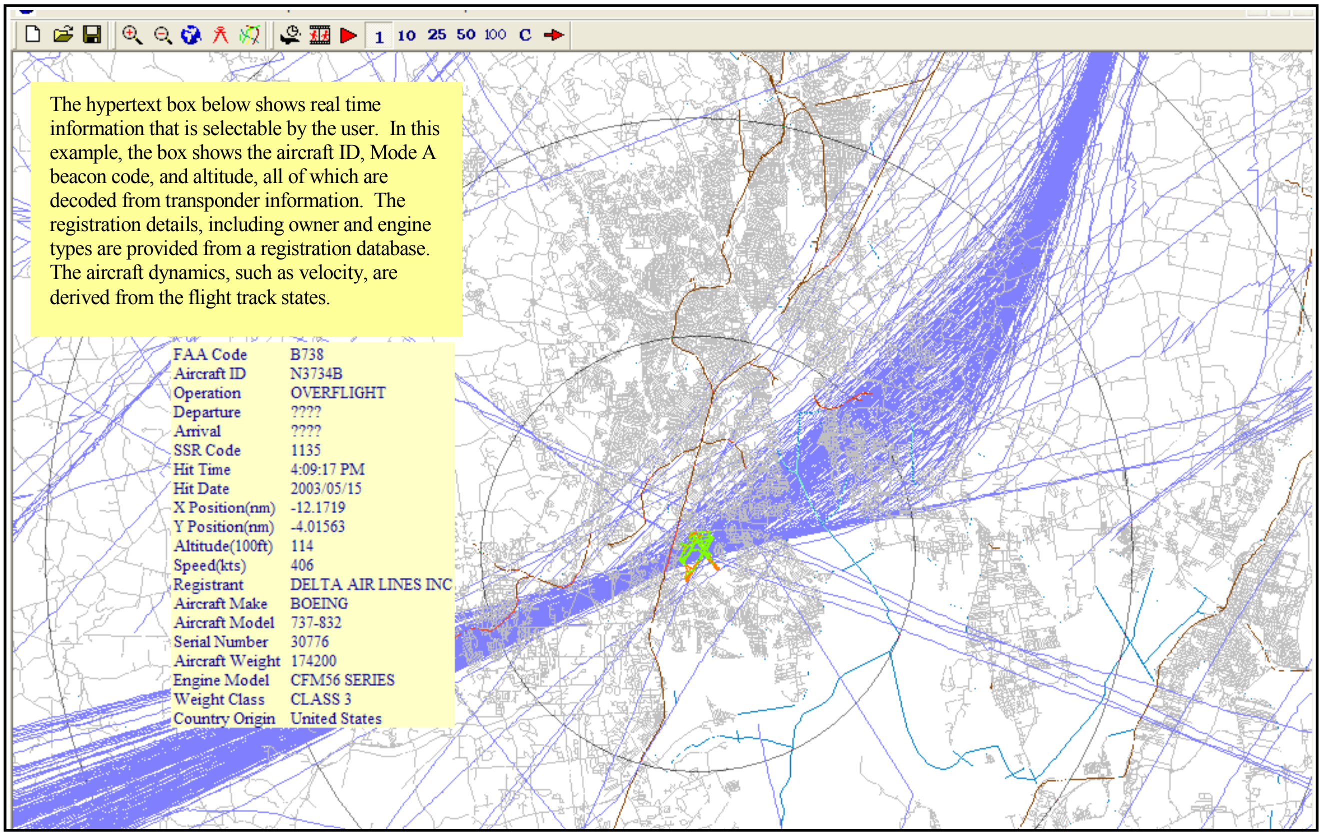


Figure 1. Example Showing Tail Number Derived from Mode S

source of information that is useful for airport management. As aircraft exchange data with their operations centers, which is many times per flight, all messages contain the aircraft's flight number and tail number/registration. Therefore a by-product of the e mail service is another source of correlated flight number and tail number, which is very useful to fill in the blanks for foreign aircraft, new U.S. aircraft, or U.S. aircraft that have recently been transferred but not updated in commercial databases. After extensive field trials in the late 1990's Rannoch was awarded U.S. patents on these techniques, [Refs. 1 & 2]. The ACARS source of tail numbers and flight numbers is a real-time source, and more current than any published commercial database. One of the main features of this approach is that it allows an airport to automatically update Mode S/registration details on an ongoing basis, in real time.

Voice Recognition Acquisition of Tail Number

The ***fourth tail number source*** that can be used is mainly for general aviation (GA) aircraft. Based on research conducted by the authors in the late 1990's it was possible to tag GA aircraft that did not have a Mode S transponder with a tail number corresponding to the aircraft call sign [Ref. 3]. ATC will refer to GA aircraft operating in VFR around towered airports by their tail number. Initially, an audio recording that was time synchronized with the flight track was used, so that when played back, airport management could decipher the tail number from the voice communication between ATC and the pilot. While effective, this was an inherently manual process and for airports with high traffic it was manually intensive and not practical in many situations. Algorithms were then developed to associate flight tracks with the voice communications and to perform automatic voice recognition on the pilot-controller exchanges to identify the aircraft N number, or tail number.



The hypertext box below shows real time information that is selectable by the user. In this example, the box shows the aircraft ID, Mode A beacon code, and altitude, all of which are decoded from transponder information. The registration details, including owner and engine types are provided from a registration database. The aircraft dynamics, such as velocity, are derived from the flight track states.

FAA Code	B738
Aircraft ID	N3734B
Operation	OVERFLIGHT
Departure	????
Arrival	????
SSR Code	1135
Hit Time	4:09:17 PM
Hit Date	2003/05/15
X Position(nm)	-12.1719
Y Position(nm)	-4.01563
Altitude(100ft)	114
Speed(kts)	406
Registrant	DELTA AIR LINES INC
Aircraft Make	BOEING
Aircraft Model	737-832
Serial Number	30776
Aircraft Weight	174200
Engine Model	CFM56 SERIES
Weight Class	CLASS 3
Country Origin	United States

Figure 2. Example Showing Registration Details Derived from Mode S

The algorithms would basically screen the data to digitize and identify voice communications for phrases stating with N123, etc. During early field trials at major airports over 90% correct correlation of aircraft and voice recognition data was achieved. However, the success of this approach is dependent on the ATC phraseology and communications decoding methods used and it was found that at some airports the order of 50% successful decoding of N number and association with the flight track could be achieved. Nevertheless, this is a fairly good technique that helps with the identification of specific aircraft, and more importantly helps with automation of the process of identifying and tracking tens of thousands of flights per year at airports.

Emissions and Noise

Many organizations predict that the single biggest constraint to airport growth in the near future will be the result of environmental concerns. Residents in noise impacted areas have stifled many runway expansion proposals, resulting in less than 5 additional runways at the 30 busiest airports in the U.S. within the past 10 years [Ref. 4]. It is therefore very important for airports to manage environmental issues on a local basis. An important tool for the management of noise is the development of accurate airport noise contours. Noise contours summarize the noise levels from airport operations on a daily, weekly, or annual basis. Figure 3 is an example of noise contours at an airport, where contours are shown usually from 55 dB and higher in 5 dB increments, for day-night level (DNL) equivalent noise. (This figure is provided courtesy of Harris Miller Miller and Hanson Inc.).

One of the limitations of contour plots is that their accuracy is dependent on the information available from aircraft flight track sources. If the aircraft type is unknown, or information on the aircraft is not available then estimates must be used which leads to inaccuracies in the contour plots. Hullah [Ref. 5] noted that when using flight track data, a missing parameter to calculate accurate noise contours is engine thrust. Thrust can be calculated from the following formula and the associated Integrated

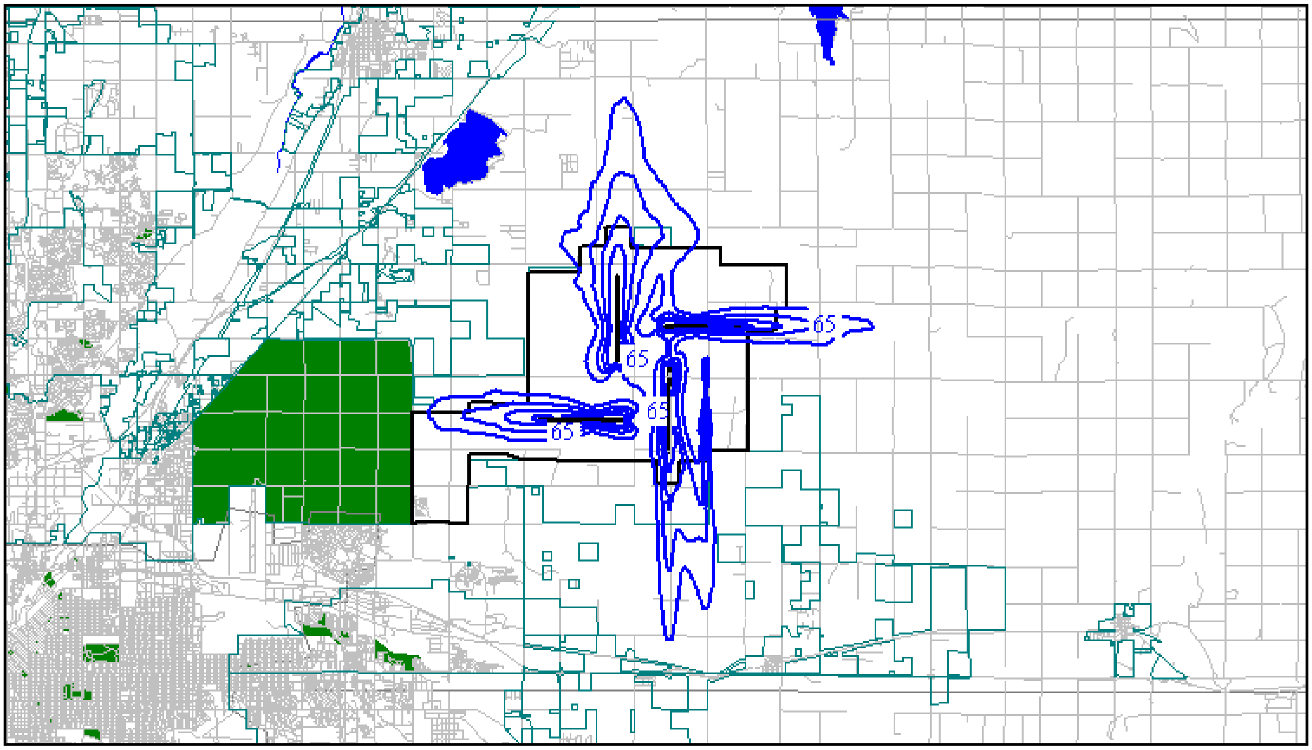


Figure 3. Airport Daily Noise Contours

Noise Model (INM) thrust and drag-over-lift coefficients databases [Ref. 6].

For departures, the following equation is used to calculate the Corrected Net Thrust per engine:

$$F_n/\delta = E + Fv + G_A h + G_B h^2 + H\, T_C$$

Where:

F_n/δ is corrected net thrust per engine (lbs),
δ is pressure ratio at aircraft altitude,
v is equivalent/calibrated airspeed (knots),
h is pressure altitude (feet) MSL,
T_C is temperature (°C) at the aircraft,
E, F, G_A, G_B, H: Jet coefficients that depend on power state (max-takeoff or max-climb power).

One of the parameters used in the above equation is the Calibrated Air Speed (CAS), which can only be obtained if wind speed, temperature and air pressure are known. If these parameters are known, they enable calculation of CAS from ground speed under the following formula:

$$v = v_T\, \sigma^{1/2}$$

Where:

v is calibrated airspeed (knots),
v_T is true airspeed (= 3-D ground speed corrected for wind vector component),
σ is air density ratio at aircraft altitude.

For arrivals, the following equation, based on the zero-total-force principle, is used to calculate the Corrected Net Thrust per engine:

$$F_n/\delta = (W/\delta)\,[R_f - \sin(\gamma) / 1.03] / N$$

Where:

(F_n/δ) is corrected net thrust per engine (lbs),
W is approach or touch-and-go weight (lb),
δ is pressure ratio at aircraft altitude,
R_f is drag-over-lift coefficient that depends on flaps and gear setting,
γ is average descent angle,
N is number of engines.

Analyses from trials conducted by the authors in the Washington DC area provided data sets for several thousand aircraft. The data included flight tracks, aircraft actual weight and other environmental data. The findings were significant for supporting in-depth noise and emissions modeling and validation, and auditing activities [Ref. 7]. The samples below were collected in May and June 2003 from the tracking system in Washington DC. The system included a wide area multilateration tracking system with six sensors and 4 channel ACARS decoding and correlation. The samples show the types of information available on from flights, including:

- Actual aircraft weight and fuel on board, which is useful for calculating thrust, aircraft noise, and emissions. Thrust is derived from knowing the aircraft type and actual weight, the type of engines used on the aircraft, and the aircraft's dynamics and configuration (e.g., aircraft departing, climbing, accelerating).
- Number of passengers on board, which is useful for several purposes including auditing of passenger-based landing fees and ticket tax revenues.
- Actual aircraft surface and outside air temperature, as well as wind speed and direction around the aircraft, which is useful for modeling of perceived aircraft noise and emissions modeling.

<u>Aircraft Sample 1</u>

<u>Aircraft Data</u>

Manufacturer: MCDONNELL DOUGLAS
Model Name: MD-10-10F
Aircraft Type: Fixed Wing Multi-engine
Engine Type: Turbojet
Number of Engines: 3
Aircraft Code: 3022112

<u>Engine Data</u>

Manufacturer: GE
Model Name: CF6-6
Engine Type: Turbojet
Thrust: 40,000 pounds
Engine Code: 30020

<u>Other Data</u>

Position: N392052 W0775637
Altitude: 34,327 feet
Surface Air Temp: -048 degrees F
True Air Temp: -018 degrees F
Wind: 314 degrees, 25 knots
True Air Speed: 484 knots
Cruise Speed: M0.82
Fuel on Board: 66,200 pounds
Date: 5/20/2003
Time: 18:32:10

<u>Aircraft Sample 2</u>

<u>Aircraft Data</u>

Manufacturer: AIRBUS INDUSTRIE
Model Name: A319-112
Aircraft Type: Fixed Wing Multi engine
Engine Type: Turbojet
Number of Engines: 2
Number of Seats: 179
Aircraft Code: 3930323

<u>Engine Data</u>

Manufacturer: CFM INTL.
Model Name: CFM56 SERIES
Engine Type: Turbojet
Thrust: 22,000 pounds
Engine Code: 13802

<u>Other Data</u>

Aircraft Zero Fuel Weight: 110,065 pounds
Fuel on Board: 12,354 pounds
Aircraft Ramp Weight: 122,419 pounds
Maximum Takeoff Weight: 141,900 pounds
Passengers on Board: 91
Mean Aerodynamic Chord: 28.4%
Stabilizer Setting: 0.6 Degrees up

As shown in Figure 4, weight information, engine identification, environmental data, and the aircraft flight dynamics are used to calculate aircraft thrust which in turn allows noise interpolation with distance and engine emissions modeling. Since the multilateration tracking system offers accurate tracking with a high once per second update many flight dynamic parameters can be derived, including velocity, acceleration, deceleration etc.

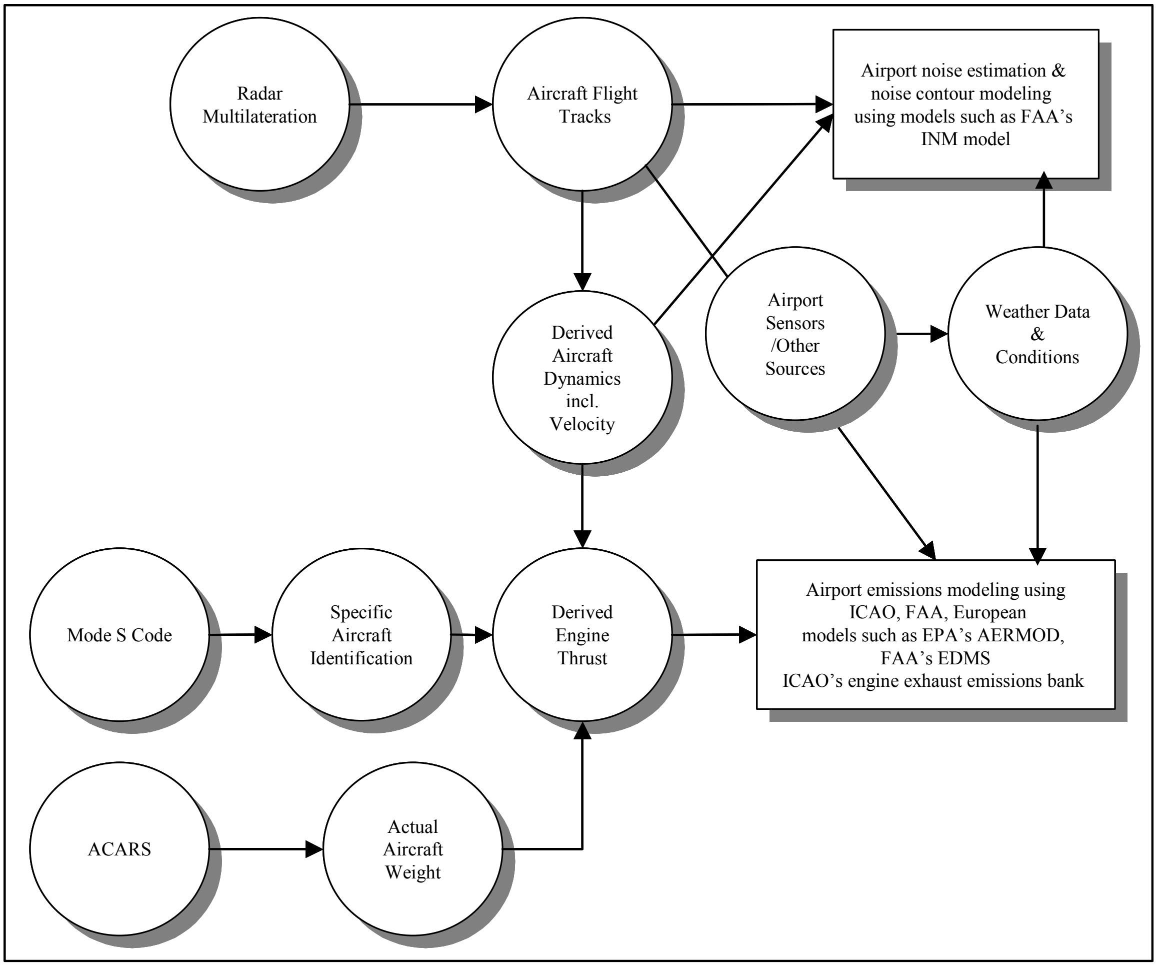


Figure 4. Using Calculated Thrust to Model Noise Levels and Emissions

Conclusions

The techniques presented in this paper bring to a new level the decision support information available to airport and airline management staff. Having ongoing automated access to high fidelity data on airport operations allows airport management to monitor, analyze and predict the impact of operations. Through a unique fusion process, this approach provides this data, digitally, and in a form that is integrated with flight tracks, noise events, and other data. Until now, approaches have not offered any type of automated correlation of operational information with noise and flight track data. This approach offers users the ability to record, search and query vast numbers of records using all of the above parameters, where available. The data are essential for today's airport and airline managers, who simply cannot manually investigate the impact of thousands of operational events that occur at a typical airport.

This paper presents a practical automated approach to provide airport managers and operations staff with this information in a way that is easy to use. The authors plan to validate the emissions and noise modeling results from several airports using these techniques in late 2003.

References:

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