Concept of Operations for Oceanic Tailored Arrivals

DRAFT

*Tailored Arrivals (TA) is a comprehensive method of planning, communicating, and flying highly-efficient arrival trajectories from cruise altitude to the runway threshold**.** TA trajectories are optimised for each aircraft to permit a fuel-efficient, low-noise descent profile that will provide separation assistance while complying with arrival sequencing requirements and other airspace constraints. With airline partnership and FAA support, NASA Ames and Boeing have recently embarked on a collaborative R&D effort aimed at TA concept exploration and system validation in the U.S. This effort will initially focus on trans-oceanic arrival operations due to the availability of airborne and ground-based data-link support infrastructure present in the oceanic control environment. The purpose of this document is to describe a general, end-state, Concept of Operations (CONOPS) applied to trans-oceanic operations, referred to herein as Oceanic Tailored Arrivals (OTA). This CONOPS describes the scope, assumptions, and potential benefits associated with OTA, together with general system requirements and procedures for the airspace user and Air Navigation Service Provider (ANSP). This CONOPS is intended to provide a framework for advocacy and planning in preparation for a near-term flight demonstration involving trans-pacific commercial arrival operations in the 2006 timeframe.*

1. Introduction

During the next decade the demand for FAA Air Traffic Services in the Oceanic Domain is expected to double (Ref. 1). At the same time, there is a considerable demand for airline cost reductions and improved operational efficiency. Currently, oceanic air traffic accounts for approximately 4% of the total air carrier traffic count in US controlled airspace. This relatively small portion of the total traffic load generates 20% of the air carrier passenger revenue and 49% of their cargo revenue each year (Ref. 2). As the demand for trans-oceanic air travel increases, improvements to procedures and services are essential to preserve or increase these financial benefits. The continued demand for use of congested airspace and airports throughout the National Airspace System (NAS), combined with increasing pressures on air carriers to realize economic benefits, are generating global interest in the need to modernize air traffic operations, remove procedural inefficiencies, and establish global standards for interoperability (Ref. 3). In the U.S, these concerns are being addressed by the Joint Planning and Development Office (JPDO) in preparation for the Next Generation Air Traffic System (NGATS).

Oceanic Tailored Arrivals (OTA) represents an important step towards NGATS by leveraging capabilities currently available in Air-Traffic Management (ATM) and aircraft automation systems. OTA is a means of planning, communicating, and flying highly-efficient arrival trajectories from cruise altitude to the runway threshold, and beginning the operational transition to 4D Trajectory Management. These strategic, *trajectory-oriented*, arrival solutions are designed to satisfy ATM constraints associated with separation, spacing, and sequencing, while allowing pilots to rely upon the FMS to manage and execute continuous, fuel-conservative, low-noise, descent profiles. With OTA, the efficiencies gained through careful planning and execution of en route oceanic flight legs can be extended rather than compromised in the arrival airspace domain.

1.1 Background

With airline partnership and FAA support, NASA Ames and Boeing have recently embarked on a collaborative R&D effort aimed at developing and demonstrating the concept of Tailored Arrivals in the Continental U.S (CONUS). The decision to focus initially on trans-oceanic arrival operations was based on the current availability of supporting airborne and FAA equipage and data-link infrastructure. For example, the integrated airborne Communication, Navigation, and Surveillance (CNS) capabilities required for OTA are available in aircraft currently equipped with the Future Air Navigation System (FANS), which includes a high proportion of Boeing and Airbus aircraft assigned to trans-pacific routes. On the ground, ATM CNS automation required to support OTA is available through the FAA's Ocean 21 system, currently in various stages of deployment at the Oakland, New York and Anchorage Air-Route Traffic Control Centers (ARTCCs).

A number of flight demonstration activities associated with Tailored Arrivals have been carried out in the U.S and abroad. Most recently, an in-service demonstration was conducted by Airservices Australia in 2004, in partnership with Qantas Airlines, Boeing and the Air Traffic Alliance. In this evaluation, static TA clearances were issued by data-link to B-747 and A-330 aircraft during non-congested arrival operations into Melbourne and Sydney. Planning is currently underway in Europe for a similar evaluation in more congested and complex airspace (Ref. 4). Other related activities include Continuous Descent Approach (CDA) field trials conducted at Louisville in 2002 and 2004 with United Parcel Service (UPS), similar CDA trials currently underway with UPS at Mather airport near Sacramento, and RNAV arrivals into Atlanta (Ref. 5). Although these activities share similar economic and environmental benefit objectives, the procedures, and equipage employed vary across each demonstration activity based on the specific operational objectives and the system and airspace constraints involved at each site.

The OTA CONOPS described here builds upon the validated benefit mechanisms and findings associated with these prior field demonstrations, while highlighting the key role of Ocean 21, FMS/data-link integration, and new controller tools for constructing Tailored Arrival solutions under more challenging, capacity constrained, airspace conditions. OTA will borrow extensively from past research at NASA aimed at incorporating user-preferred trajectories into modern air-traffic controller decision-support tools. This research has involved numerous simulation and field test activities based on NASA's Center-TRACON Automation System (CTAS). Two CTAS efforts directly related to OTA are the En Route Descent Advisor (EDA), and the En Route Data Exchange (EDX) R&D activities (Refs. 6 & 7).

As an initial step towards validating and deploying the capabilities outlined in this CONOPS, a collaborative, in-service, demonstration of OTA involving trans-pacific arrivals to the west coast is being planned for 2006. This initial demonstration will limit the delivery of OTA clearances to select aircraft during periods of relatively low congestion. Pending FAA approval, the proposed evaluation will be conducted at the Oakland ARTCC (ZOA) in close coordination with the FAA and United Airlines. Additional airline partners and FAA facilities are also being considered.

2. Problem Description

The OTA concept has the potential to alleviate numerous problems inherent in the current ATM system. By enabling airspace users to routinely execute strategically planned, continuous descents at minimum power from cruise altitude to runway threshold, efficiency gains can be realized in the following key areas:

Fuel & Time Savings:

In recent years, substantial time and fuel savings have been made possible through recent advances in oceanic traffic management and avionics technology. These savings are associated with the introduction of flexible track assignments, reduced separation criteria associated with more stringent Required Navigational Performance (RNP) airspace, and advances in FMS guidance, navigation, and control. However, to the frustration of the airspace user, efficiency gained en route is often squandered during the final stages of flight as an aircraft enters the arrival airspace domain. As an aircraft transitions for landing, ATM procedures required for general flow management, sequencing, and spacing commonly interrupt an aircraft's descent by forcing temporary altitude assignments, excessive vectoring, and airborne holding. Tailored Arrivals have the potential to alleviate this lost benefit, by providing dynamic profile clearances that retain the efficiency characteristics of cruise-to-threshold paths for the FMS to execute, while respecting and serving the needs of sequencing and conflict avoidance as traffic becomes congested.

Capacity:

Oceanic arrivals to congested domestic airspace and airports need to be properly scheduled and sequenced into the general arrival flow in order to achieve maximum throughput under capacity constrained conditions. The recent introduction of time-based metering tools such as the CTAS Traffic Management Advisor (TMA) has greatly improved the controller's ability to establish effective schedule and sequence requirements for optimal throughput. Although these tools take airport capacity into account, the schedules generated only go as far as a metering fix located at the TRACON boundary, after which controllers must rely upon traditional scheduling and sequencing methods to realize actual throughput to the runway. More importantly, controllers lack specific Decision Support Tools (DST) to assist them in developing strategic and efficient maneuver solutions to accurately deliver aircraft to metering fixes in accordance with scheduled arrival times (Ref. 8). This can result in incomplete saturation of a TMA metering fix, which can lead to excessive inter-arrival spacing at the runway threshold, resulting in reduced throughput. Oceanic Tailored Arrivals offer the potential to fully integrate aircraft automation with ground-based DSTs designed for maximizing throughput under capacity-constrained conditions. Closing the loop between ground-based and airborne systems in this manner improves the execution of capacity-related ANSP initiatives, and provides both systems with a common picture of 4-D flight path intent following strategic clearance uplink/delivery.

Workload:

In today's environment, the merging of oceanic traffic into domestic arrival flows under capacity-constrained conditions results in a high workload environment for both controllers and pilots. Today, ATM actions for separation, sequencing, and spacing are typically carried out in an iterative, tactical fashion, resulting in frequent and aggressive maneuvering that increases workload for both the ANSP and the airspace user. For example, a controller attempting to deliver an aircraft on time to a metering fix might initially choose a series of progressively lower altitude assignments. If these control actions are insufficient to absorb the required amount of delay, and/or separation conflicts develop during the descent, the controller may need to resort to vectoring together with additional speed and altitude clearances. With the availability of strategic descent management tools, the controller could have chosen a single speed adjustment, prior to the aircraft's Top-of-Descent (TOD) that would have solved the combined metering and separation problem while allowing the aircraft to carry out a non-interrupted, minimum-fuel, descent. TA provides a mechanism to deliver these single, comprehensive arrival solutions to the flight deck in a timely manner that accommodates review by the flight crew and entry into the FMS. Upon FMS entry, feedback is provided through data-link to confirm that aircraft automation will perform as intended by the ground system.

Utilization of currently available flight deck and ATM automation (for flight planning):

The absence of ground-based radar in the oceanic environment has created a strong incentive for the introduction of state-of-the-art ATM and flight-deck automation. A high proportion of aircraft assigned to trans-pacific routes are now equipped with a FANS 1/A avionics system that provides integrated CNS capabilities. Through a FANS 1/A service referred to as Contract Aircraft Dependent Surveillance (ADS-C), automated position reports are data linked to ATM over satellite, VHF, or HF sub-networks, according to the performance requirements of the airspace involved. Communication with ATM, including receipt and acknowledgement of routine clearances, is supported by the Controller Pilot Data Link Communications (CPDLC) service, also supported by FANS 1/A. Upon pilot receipt and acceptance of CPDLC messages, FANS 1/A supports the loading of flight plan amendments and other ATM clearances into the aircraft FMS for guidance and control. ATM ground support for these CNS services is now provided in a seamless and integrated manner through the FAA's newly introduced Ocean 21 system.

This integration of airborne and ground-based CNS infrastructure in the oceanic environment presents an opportunity for introducing new advances in flight management efficiency. The FMS is ideally suited for managing and executing *trajectory-oriented* flight plans, i.e., flight plans and profiles generated with strategic time horizons that traverse multiple sectors of controlled airspace. Due to today's *sector-oriented* ATM environment that inherently limits planning to a single controller's sector or facility, flight crews are often forced to limit the use of the FMS in complex arrival airspace regions, thereby limiting the efficiency gains and predictability offered by four-dimensional (4D) FMS equipage. In today's environment, planning efficiency is further limited by the fact that arrival clearances are issued by voice. In a voice-only environment, the complexity of communications between pilots and controllers must be held to manageable levels, thus limiting the exchange of trajectory-oriented arrival solutions, even where such solutions are available. In some cases, voice issued clearances are less conducive to entry into onboard CNS systems (e.g. heading instructions), further limiting the potential for using the onboard automation to provide more efficient profiles for the aircraft operator, and more predictable profiles for the ATM system and the controllers using that system, OTA offers a means to overcome these problems, by driving the integration between air and ground systems.

Sharing of data and Accommodation of user preferences:

It has long been recognized that substantial operational improvements can be offered through the routine exchange of information between the airspace user and ANSP (ref. 9). This information includes aircraft parameters, airspace-user flight plan preferences, and ANSP constraints. The availability of real-time aircraft data such as weight, airspeed, magnetic heading, Top of Descent (TOD), Estimated Times of Arrival (ETA), and atmospheric conditions can improve controller decision making and related DST performance. Knowledge of dynamic airspace constraints can improve planning by flight crews, resulting in requests that are more likely to be granted by the ANSP. Moreover, access to airspace user preferences by the ANSP can result in control decisions that are more favorable to the operational needs of a particular flight or airline. Although a large body of research exists demonstrating the benefits and feasibility associated with air-ground data exchange using current equipage, there has been little in the way of operational implementation. Oceanic Tailored Arrivals provide a means to gather valuable and early experience with both the type and quality of the data that can be obtained from an aircraft, and its utility in ground tools. Through the use of existing infrastructure, OTAs provide a means to corroborate and extend the results achieved through simulation with real-time data from in-service operations.

Noise and emissions:

Noise and emission restrictions are increasing throughout the NAS due to increasing environmental awareness and closer proximity of airports to residential districts. In response, many airports are forced to restrict the number, type, or periods of operation, thereby limiting accessibility to passenger and cargo services, while negatively effecting airline profits. Studies suggest that the majority of noise and emissions perceived by the public are generated as a result of aircraft having to level-off and add power at low altitude in response to ANSP procedures for spacing and sequencing for final approach and landing (Ref. 5). OTA trajectory profiles are designed to allow aircraft to descend at minimum power settings while minimizing, or eliminating, the need for temporary level-offs and associated power transients, thereby helping to alleviate environmental concerns.

Airspace Integration:

Future concepts for ATM, including those developed by the Joint Planning and Development Office (JPDO) in preparation for the Next Generation Air Traffic System (NGATS), revolve around the use of 4D trajectories and the use of these trajectories across multiple controlling sectors and centers. These concepts all rely on the capability to coordinate, deliver, and execute clearances that stretch through the controlled airspace of more than one ATM sector, Center, or domain, each with distinct operating characteristics in today's NAS (e.g. Oceanic, En-Route Domestic, Terminal). The transition from today's sector-oriented operations to the 4D, trajectory-oriented, world of NGATS requires that new procedures and mechanisms be developed and demonstrated. OTA provides an early opportunity to define and implement safe and reliable trajectory-oriented clearance coordination and delivery mechanisms, significantly reducing the deployment risk and lead-time for realization of NGATS solutions.

3. The OTA Solution

3.1 Concept Overview

Mature Implementation:

With OTA, controllers are able to develop customized, dynamic, arrival solutions that transcend multiple regions of controlled airspace in order to enable efficient, uninterrupted descents from cruise altitude to runway threshold. In a mature implementation, OTA is supported by ground-based automation capable of computing fuel-efficient descent solutions in the presence of complex traffic constraints and airspace restrictions. With the aid of a descent planning tool such as the CTAS En Route Descent Advisor (EDA), OTA solutions can be constructed that account for constraints such as aircraft performance limits, STAR restrictions, scheduling and sequencing requirements, intermediate crossing restrictions, and strategic separation requirements.

Working in conjunction with the FAA's Ocean 21 system, EDA will allow the Oceanic controller to develop OTA solutions well prior to an aircraft's Top-Of-Descent (TOD) point. In order to develop these solutions, EDA must be capable of computing accurate trajectory predictions over time horizons of 30 minutes or more. These predictions will leverage CTAS aircraft performance models, flight plan intent, and additional aircraft state data obtained from routine ADS-C down-links (Ref. 6).

The comprehensive OTA descent solutions are translated into clearance instructions for communication via data-link to the flight deck. Prior to clearance delivery, OTA clearances and associated intent data are shared, and coordinated for approval, across the En Route Domestic and TRACON ATM facilities that the aircraft is expected to traverse. Although the mechanics of this coordination and approval process are a subject of ongoing research, the process is expected to be largely automated through the integration of the FAA's Ocean 21, ERAM, and STARS automation platforms. In the event that, due to traffic complexity, the entire OTA trajectory can't be approved or flown to the runway, the trajectory clearance may be adapted by the controller to deliver the aircraft to an intermediate point, such as a meter fix at the TRACON boundary, or STAR waypoint.

Once up-linked to the flight deck in the form of a FANS-1/A CPDLC route clearance, the trajectory associated with the OTA clearance is loaded as a modified route into the FMS and reviewed by the flight crew. If acceptable the flight crew executes the new trajectory, which will now be flown by the aircraft's FMS. The flight crew accepts the OTA clearance via data link, thus closing the loop with the controller. Throughout the remainder of the flight, the controller and the flight crew are able to monitor the aircraft's progress along the OTA trajectory. The monitoring of aircraft conformance and current flight intent is facilitated by the routine exchange of trajectory-related parameters from aircraft to ANSP. To ensure that the ANSP and airspace user have a common trajectory model in their respective automation systems, aircraft state data is routinely down-linked to the ANSP, while current wind forecasts along the descent path are up-linked to the flight deck. If necessary, an aircraft can be taken off of its OTA trajectory at any point during the descent. Although not expected to be complex, the procedures for discontinuing an OTA clearance in the presence of traffic constraints are a subject of ongoing research. With the assistance of EDA, a new or updated OTA solution can be computed at any time, as desired by the controller.

In a mature implementation, the OTA concept is intended as a normal operating procedure, applicable to all trans-oceanic traffic inbound to the CONUS. The incorporation of similar procedures for use in the domestic NAS will be addressed in a related, but parallel, effort.

In summary, OTA clearances in a mature implementation (as illustrated in Fig. 1) will be constructed to:

- Conform to specific aircraft type and expected landing configuration
- Satisfy traffic flow management requirements, airspace restrictions, and SOPs
- Provide strategic separation assistance through trajectory probing/planning
- Coordinate across ANSP facility boundaries
- Allow delivery by data-link for workload and flexibility considerations
- Permit easy loading into the aircraft FMS for crew verification and flight execution
- Allow for a continuous, near-idle descent to the runway threshold (when traffic conditions permit)
- Allow clearance break-away and/or revision any time during the arrival

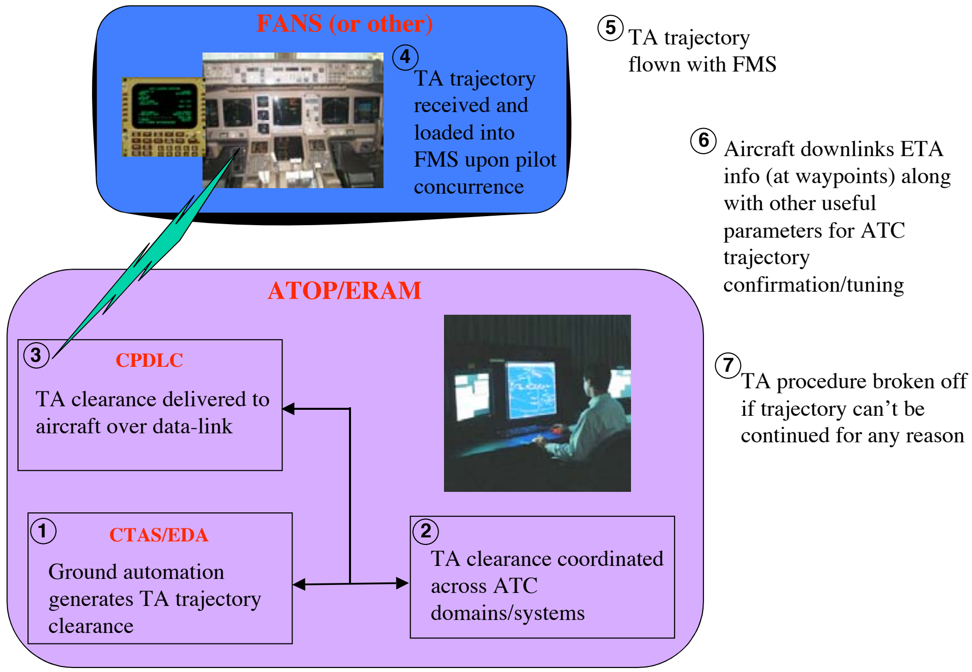

Figure 1: Mature OTA Concept Illustration

Near-Term Implementation:

In the near term, the OTA concept will be applied to relatively low-congestion traffic environments in which static OTA procedures for minimizing fuel burn and environmental impact can be flown. Unlike the mature implementation, near-term OTA will not require the support of ground-based EDA automation to generate flexible solutions in the presence of traffic management constraints. Instead, OTA trajectories will be selected from a limited set of predefined, static profiles and procedures. Near-term OTA will be applied under conditions in which pilot-discretionary descents are often employed today. The advantage of OTA over pilot-discretionary descents is that accurate intent data can be shared between the airspace user and ANSP, thereby improving coordination and reducing the likelihood of trajectory interruptions. Cross-airspace coordination is also formalized with OTA, making pilot discretionary descents more routinely available. Near-term OTA will allow continuous descent management to the runway threshold with minimal communication required between controllers and flight crew.

Because of their static nature, OTA clearances can be delivered by either data-link or voice, depending on aircraft equipage and controller preference. To support clearance delivery by voice, published OTA procedures will be incorporated that are applicable across a wide variety of aircraft types. The use of data-link in near-term OTA applications offers the advantage of alleviating FMS storage requirements; i.e., detailed speed, altitude and routing constraints associated with a given procedure can supplied from the ground without having to "source" the information from the FMS itself, thereby allowing a wider range of static OTA procedures to be utilized.

3.2 Trajectory Specification

The TA concept is based on the idea of specifying arrival trajectories through a series of speed, altitude, and routing constraints. These constraints are formulated in order to allow aircraft to execute a continuous, fuel conservative, descent while satisfying airspace and traffic-management requirements, as defined by separation standards, scheduling and sequencing initiatives, intra-facility Standard Operating Procedures (SOPs), and inter-facility Letters of Agreement (LOAs). Under complex traffic conditions, TA trajectory clearances must be formulated in a manner sufficient to provide a degree of certainty over the future location of an aircraft in both space and time, i.e., in 4D. A key feature of the TA concept is that, under lightly constrained traffic conditions, the resulting trajectory solutions will closely resemble those computed entirely by the aircraft FMS for minimum fuel. Regardless of traffic complexity, TA provides a "hand shake" between the ANSP and airspace user that provides for situational awareness and shared flight path intent.

Although TA enables 4D arrival management, it is not based on exchanging complete 4D trajectory computations between the air and ground. Instead, the arrival trajectory is specified by a series of profile constraints, applied either at discrete points along the trajectory or along specific trajectory segments. For example, as shown in Fig. 2, the TA trajectory (shown in orange) is defined by a series of speed and altitude constraints at specific points/fixes along the descent path. If required to fully satisfy traffic/airspace objectives, these discrete altitude and speed constraints can be applied to various routing options, defined by dynamically selected waypoints that take advantage of aircraft RNAV capabilities.

Alternatively, or in combination with the discrete constraints shown in Fig. 2, TA trajectories can be specified by airspeed targets to be maintained along path segments. These airspeed targets can be communicated as either Calibrated Airspeed (CAS) or Mach number, depending on the altitude the aircraft is flying[1]. Depending on traffic management objectives, these Mach/CAS profile constraints can be applied to the remaining cruise phase of flight, descent phase, or both cruise and descent phases. Assuming an idle-thrust descent for jet transports, the arrival trajectory can be completely specified by a Mach/CAS speed profile in conjunction with a targeted altitude/speed crossing restriction. As illustrated in Fig. 3, the TOD point can be computed onboard by the FMS as a by-product of the speed profile constraints and crossing conditions communicated in the TA clearance. This leverages flight-deck automation while reducing the complexity of the clearance information exchanged. As with discrete speed/altitude constraints, these along-path profile constraints can be combined with route

[1] Aircraft operational envelopes are limited by Mach number rather than CAS at higher altitudes in order to prevent performance degradation due to sonic effects.

modifications that either stretch or shorten the trajectory, as required for traffic management.

Representing TA trajectory solutions with simple profile constraints not only simplifies the information required to be exchanged, but also allows for the simple modification or amendment of TA clearances through the exchange of a minimal set of updated constraints. For example, if an aircraft subject to time-based metering is required to absorb an additional minute of arrival delay to a meter fix, a new TA clearance conveying a slower descent CAS could be communicated over data-link and loaded into the FMS upon pilot concurrence. In this manner, an entirely new trajectory solution can be computed and flown by the FMS based on a single amended speed parameter communicated by the ANSP.

The range of feasible profile constraints to be used in specifying a TA clearance is dependent on the automation systems available on the ground and flight deck, along with the air-ground communication and integration capabilities that exist. Existing research is focused partly on exploring the full range of TA trajectory specifications that can be used in formulating TA clearances based on existing air-ground capabilities. The leveraging of onboard Required Time of Arrival (RTA) capabilities in conjunction with ANSP-generated TA profile constraints is currently being explored as an additional refinement to the TA concept.

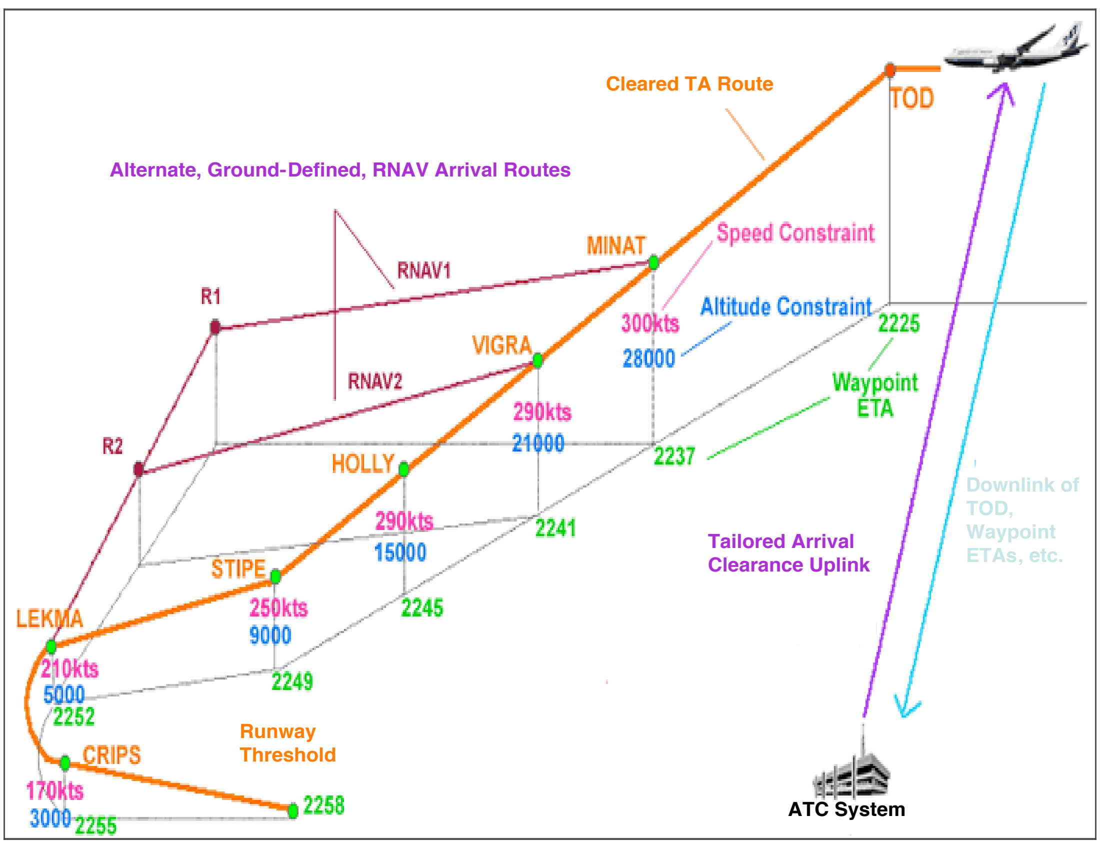

Figure 2: Tailored Arrival with Profile Constraints at Discrete Points

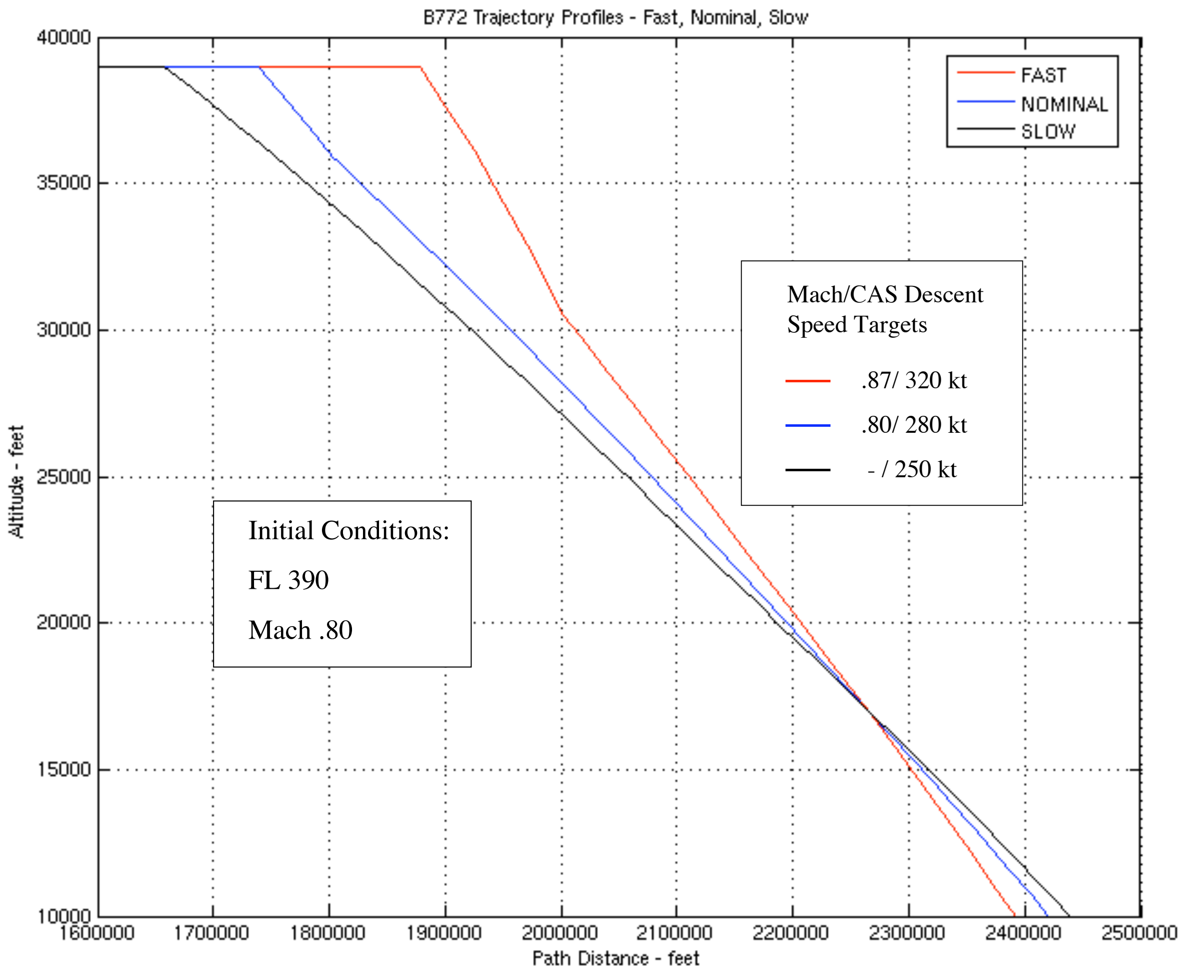

Figure 3: Tailored Arrival Trajectories for Boeing 777-200, Defined by Constant Airspeed Targets During Descent

3.3 Operational Procedures/Scenarios

The scenarios outlined below are intended to convey the basic series of events associated with the generation, delivery, and execution of an OTA trajectory clearance. For the purpose of this discussion, the scenarios assume a mature implementation of OTA that allows for continuous, minimum-fuel, arrival operations in the presence of moderate traffic congestion. In support of these operations, the ability of controllers to “tailor” trajectory solutions to individual aircraft types in accordance with varying airspace and traffic constraints is assumed through the use of the EDA DST.

Detailed ANSP and flight deck procedures in support of OTA are beyond the scope of this document. These procedures and associated use cases are currently being developed through human-in-the-loop simulation, in preparation for the OTA flight demonstration activity at ZOA. These procedures will be documented in the *OTA Flight Demonstration Test Plan*, currently under development by Boeing/NASA.

Nominal Operations:

A nominal operational scenario for OTA, as represented in Fig. 3, will allow for a trans-oceanic aircraft to receive a comprehensive arrival clearance well prior to the planned top of descent. The comprehensive arrival clearance will be issued by the oceanic controller using the Ocean 21 system with associated display and data-link capabilities. The tailored clearance will be designed for aircraft specific parameters to permit a fuel efficient descent. The clearance will be coordinated by ATC for traffic sequencing, airspace restrictions, and airspace usage across all facilities and sectors. The flight profile will be based on an idle thrust descent, flown by the aircraft FMS, that ideally permits an uninterrupted CDA to runway threshold.

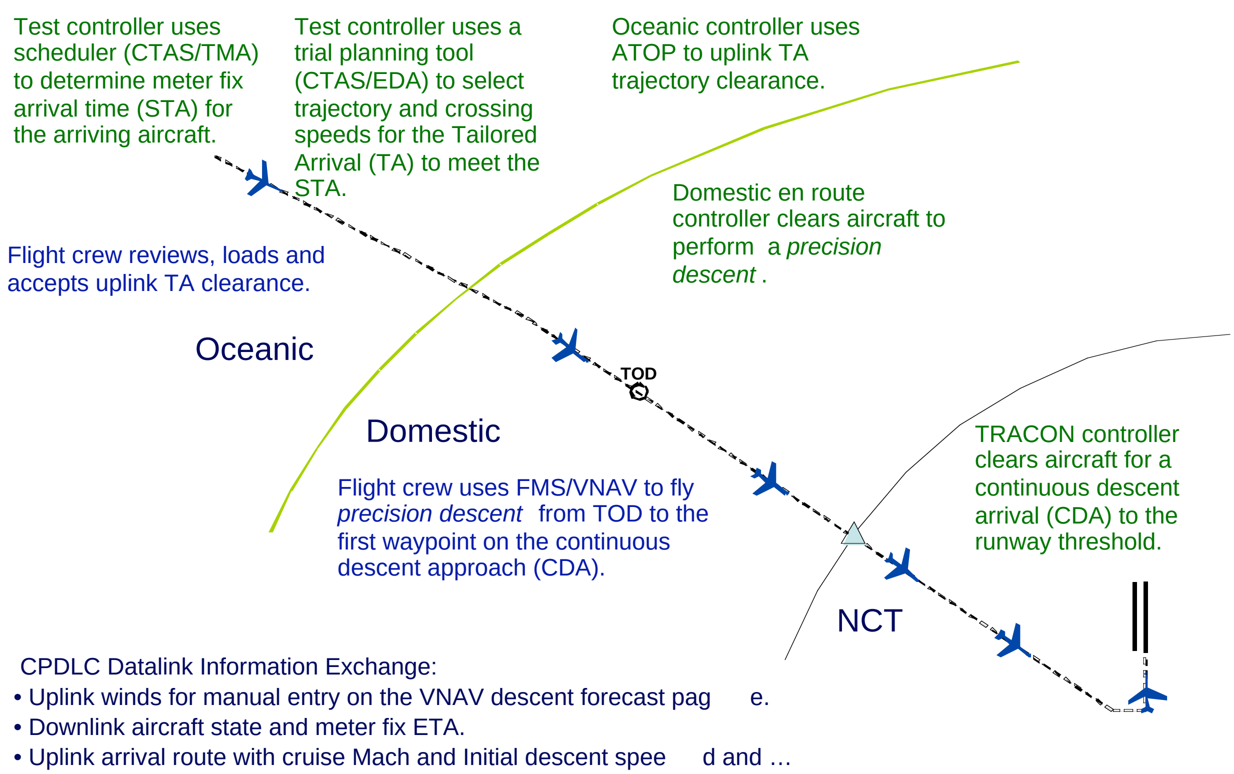

Figure 4. Nominal Oceanic Tailored Arrival

Partial/ Off-Nominal Operations:

OTA procedures will also accommodate operations when the arrival aircraft are not able to fly a complete idle thrust descent from trans-oceanic cruise with CDA continuation in the TRACON. For off-nominal conditions, the OTA procedure would provide a partial, idle-thrust descent to a pre-defined interim point (such as a metering fix, or other convenient designation). Conditions that may require partial or modified OTA operations include:

- Surface conditions at arrival airport impose restricted acceptance rate
- Heavy traffic loading in down-stream airspace (domestic en-route or TRACON) prevents the Oceanic controller from issuing a comprehensive clearance instruction all the way to the runway threshold
- Coordination between ATC domains required for comprehensive clearance delivery is problematic
- Limited aircraft equipage precludes integrated CNS/FMS procedures
- Emergent weather conditions require off-nominal routing

OTA operations and procedures under these restrictive conditions will be evaluated through system-wide and human-in-the-loop simulations as part of the NASA/Boeing research effort.

4. Benefits/Cost

4.1 Benefits

If the OTA process is employed for routine operations, substantial economic and systematic benefits can be expected based on assessments and predictions performed under previous air/ground integration studies (Ref. 5, 6, 10). Field results based on early TA flight trials in Australia, along with projections for current activities in Europe, further help in providing a solid basis for extrapolating OTA benefits across U.S. operations. Based on these prior field-demonstration and simulation studies, direct fuel savings of 400-800 lb per flight have been measured depending on aircraft size, with larger savings attributed to larger aircraft. The corresponding reduction in total flight time, associated with typical, unconstrained TA operations, is estimated at approximately 5 min per flight, depending on aircraft type and the cruise altitude from which the continuous descent is initiated. More extensive efforts to estimate quantitative benefits for both OTA and domestic TA operations on a NAS-wide basis are underway at NASA Ames. These efforts will rely on simulation experiments, combined with real-world observations obtained through flight demonstration activities such as that planned for ZOA/NCT in 2006.

The key economic and environmental benefit mechanisms expected with mature OTA operations are as follows:

- Reduced fuel burn
- Reduced flight time (under non-metering conditions)
- Reduced noise and emissions

- Reduced pilot task load (due to fewer descent interruptions and associated clearances instructions)
- Increased accommodation of airspace user trajectory preferences (enabled through shared, strategic arrival intent between the flight-deck and ATC, allowing for easier clearance amendment/negotiation)
- Improved schedule integrity (associated with more certain descent procedures under OTA)
- Reduced maintenance costs due to less engine wear (associated with fewer powered descents and level-offs)

In addition, there are numerous systematic and procedural benefits associated with OTA operations. OTA provides and early opportunity to blaze a trail towards the next generation systems and services as envisioned under JPDO/NGATS. For example, OTA provides a framework for developing and refining procedures associated with coordinating 4D trajectory clearances than span multiple regions of controlled airspace.. Furthermore, OTA provides an opportunity for airspace users to realize an improved return on their existing avionics investment, and develop further requirements for integrating airborne and ground-based automation systems (as envisioned under future deployments of ATOP and ERAM).

4.2 Costs

Routine implementation of OTA Arrivals would require corresponding costs for both the ANSP and air carriers. For the ANSP, much of the anticipated costs can be mitigated by careful integration with planned expansions of ATOP or ERAM systems. For the air carriers, OTA requires the FANS-1/A capabilities already available on a high proportion of aircraft assigned to trans-oceanic routes. For aircraft not already equipped, access to the OTA benefits in the far term would require upgrading to FANS-1/A avionics[2]. OTA benefits in the near term, however, could be achieved during low-congestion operations with no significant upgrades, assuming published procedures are in place that leverage existing air and ground navigation databases. In a far-term implementation, additional cost to the ANSP is expected to accommodate a mature integration of EDA capabilities into ATOP and/or ERAM. Although the full cost associated with EDA integration is still being assessed, it expected to offset to some degree by the FAA's existing investment in CTAS/TMA capabilities.

[2] The airline business case for FANS-1/A equipage covers a range of benefits cases; Oceanic TAs are not the only benefits attributed to FANS/1/A equipage.

5. Summary

The economic and environmental arguments for OTA are compelling. However, a number of considerations must be addressed before accurate cost/benefit comparisons are formed and fully informed decisions for procedural implementation are possible. The proposed system must be evaluated for safety and efficiency. The feasibility of implementation must be convincingly demonstrated. And, the operational requirements for both the ANSP and air carriers must be established. An initial in-service demonstration of the OTA concept is being planned at an operational air traffic control facility. This operational demonstration will be limited to single aircraft operations under permissive traffic conditions. Air carrier participation for this project has been secured. The technology supporting this demonstration will be limited to existing CNS equipment and ground-based systems. For a subset of flights, a research prototype of the CTAS EDA tool will be used to demonstrate flexible OTA solutions under more complex traffic conditions. A comprehensive Test Plan, including schedules, metrics, and support requirements is currently being prepared.

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Appendix A. Glossary

ANSP	Air Navigation Service Provider
AOC	Airline Operations Center
ATC	Air Traffic Control
ATM	Air Traffic Management
ATOP	Advanced Technologies and Oceanic Procedures
ANSP	Air Traffic Service Provider
CDA	Constant Descent Approach
CNS	Communication and Navigation System
CONUS	Continental United States
CPDLC	Controller/Pilot Data Link Communications
CTAS	Center TRACON Automation System
DAG-TM	Distributed Air/Ground Trajectory Management
DST	Decision Support Tool
EDA	En Route Descent Advisor
EDX	En Route Data Exchange
FANS	Future Air Navigation System, (1) Boeing product, (A) Airbus
FMC	Flight Management Computer
FMS	Flight Management System
IAF	Initial Approach Fix
JPDO	Joint Planning and Development Office
NAS	National Airspace System
NEXTNAS	NASA Exploratory Technologies for the National Airspace System
NGATS	Next Generation Air Transportation System
OCB	Oceanic Control Boundary
OTA	Oceanic Tailored Arrival
SFO	San Francisco International Airport
TA	Tailored Arrival
ZOA	Oakland Air Route Traffic Control Center