CTOP Industry Day

A Seminar on the Collaborative Trajectory Options Program

October 13, 2010
Collaborative Trajectory Options Program – CTOP

Industry Day

Presented to: Industry
By: Mark Novak, Manager TFM Development
Date: October 13, 2010
CTOP Industry Day Briefing  
Wednesday, October 13, 2010 8:00AM to 5:00PM

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The CTOP philosophy is to give the NAS users as much say as possible in the reroute:
- The FAA specifies the constraints
- NAS users submit their route preferences
- The CTOP algorithm gives each flight its most preferred trajectory (flight operator preferences) given the constraints

Handles negotiation electronically
CTOP
Collaborative Trajectory Options Program for the FAA

Pat Somersall
CTOP FAA Lead
FAA Operational Overview

- Change approach to TM Initiatives
  - Focus on constraint management
  - Move from defining routes to defining constraint/capacity
  - Easier to define/adjust capacity with constraint
  - Use of multiple FCA’s to define constraint
  - Solution to constraint meets all FCA capacity
  - Improved threshold management
    - Automation will maintain demand to capacity within the defined limits

Pat Somersall
CTOP FAA Lead
En route congestion realized. Flights identified with FCA, solutions modeled

ATCSCC issues a CTOP with start/stop times and capacities

TFM system issues the users most preferred option based on algorithm, given the constraints

ATCSCC may adjust time and capacity

As weather improves, CTOP provides for a natural exit strategy. Dial up capacity and CTOP increases demand allowance

Weather or flight constraint

NAS users submit Trajectory Options in anticipation of a constraint and during a CTOP TMI. These preferences are ranked based on business needs and preferences

Users can resubmit trajectory options at any time as conditions change

1. Choose route #2 - 30 minute delay
2. Choose longer route #3 - 20 minute delay
3. Stay on original route - long delay

Pat Somersall
CTOP FAA Lead
CTOP
Collaborative Trajectory Options Program for the Flight Operator

Don Wolford
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CTOP for the Flight Operator

- CTOP (Collaborative Trajectory Options Program) will soon permit a flight operator to plan a flight considering virtually all of the business goals and challenges for that flight in any given NAS constraint.

- How can the flight operator capture all the benefits of CTOP using electronic trajectory negotiation?

Don Wolford
CTOP Industry Lead
CTOP for the Flight Operator

• CTOP is a new way of doing business.

• ATC will simply manage the capacity of a constraint.

• Flight Operators, will control how each individual flight responds to a constraint.
CTOP for the Flight Operator

• Legacy FP systems may still use static route databases dependent on classic dispatch and ANSP workflows or procedures.

• Aircraft FMS nav data storage may be limited. FMS and FP system operability/storage may not be consistent across an operator’s fleet or subfleets.

• Part 91 operators may not have continuous connectivity to their FP systems.
Flight Operator considerations for electronic trajectory negotiation

- Dispatchers or pilots using such systems often must compute each considered trajectory sequentially.

- Early Intent and :NRP (National Route Program) real-time route creation functionality may not be available for flight planning.
Flight Operator considerations for electronic trajectory negotiation

- Legacy FP systems may not include all financial considerations directly related to the flight such as:
  - International overfly charges
  - Cost index (variable mach) aircraft capabilities
  - Use of :NRP (National Route Program)
  - Premium and connecting passengers, crew, or cargo
  - On time :14 (DOT list)
  - Airport curfew
  - Tarmac/surface management (HUGE)
How will “NextGen” FP systems need to deal with Electronic Negotiation?

• Virtually all of these financial considerations for any particular flight are captured or stored as formal or anecdotal data by the flight operator, and may be coarsely addressed in the flight planning process by scheduling, dispatcher or crew tribal knowledge, or manual reference to external databases and personnel.
How will Dispatch systems need to deal with Electronic Negotiation?

• An initial challenge for flight operators and FP systems will be to integrate these economic considerations as part of the flight planning process and express them in terms of the TOS (trajectory option set).

• Within the TOS many priorities can be expressed:

• Route, altitude, speed, relative priority for a particular trajectory, minimum notification time, earliest and latest time trajectory can be accepted (think both pre-Ptime, and post Ptime!).
How will “NextGen” FP systems need to deal with Electronic Negotiation?

• Flight operators will need to consider the investment in significant automation upgrades to current FP systems and messaging capabilities.

• Success will be measured as a direct relationship between the amount and robustness of data exchange between the AOC, ANSP, and cockpit.
Basic User

- No automated FP system. Pref routes and manual FP calculation only.
- No FMS or nav database.
- Time and burn only.
- Pilot files own FP. Accepts delay or requests route guidance from FSS for possible amended route.
- Cockpit asks for more direct reroute after takeoff.
User with minimal capabilities

• FP system permits single route generation. Dispatcher must manually modify route.

• FP nav database and aircraft FMS lacking full capabilities with possible sub-fleet differences.

• Business cost factors beyond time and burn-out not available.

• Dispatcher unable to file a full TOS. Must file ATCFP to get delay information, and then cancel/amend route if delay not acceptable.

• No capability for updating/resubmitting TOS. No slot swapping capabilities.

• Cockpit communication basic radio/ACARS with no FMS upload capabilities.
User with low capabilities

- FP system permits single route generation. Dispatcher may be forced to request manual route construction from back office.

- FP nav database and aircraft FMS lacking full capabilities with possible sub-fleet differences.

- Business cost factors beyond time and burn-out not available to dispatcher.

- Dispatcher files ATCFP and accepts delay, or longer route around CTOP.

- No slot swapping capabilities.

- Dispatcher advises cockpit to ask for more direct reroute after takeoff. Crew may pressure tower for early release prior to EDCT.
User with moderate capabilities

- FP system requires consecutive calculation of multiple trajectories using static route database with some routes meeting :NRP criteria. Dispatcher must do manual comparison.

- FP nav database and aircraft FMS lacking full capabilities with possible sub-fleet differences.

- Business cost factors beyond time and burn-out not available through direct automated connection to FP system. Dispatcher may apply these costs through tribal knowledge or reference to external DBs.

- Basic or manual entry of TOS information to CTOP communication tool by dispatcher. Resending of updated TOS difficult. Manual slot swapping by ATC coordinator.

- Cockpit communication basic radio/ACARS with no FMS upload capabilities.
User with high capabilities

- FP system permits simultaneous calculation and comparison display to dispatcher of multiple trajectories custom created using :NRP criteria.

- FP nav database and aircraft FMS are fully capable.

- Business cost factors beyond time and burn-out are considered in trajectory calculation: crew legalities, conex pax/cargo, premium pax/cargo, overfly charges, gate/tarmac/surface management, turn time, etc.

- Robust automation for TOS submission, awarding, slot swapping. Dispatcher may revise and resend TOS. Visual display to dispatcher of calculated trajectories and CTOP constraints on ASD/FP map.

- Robust communication with cockpit/FMS uplink.
How will Dispatch systems need to deal with Electronic Negotiation?

• Dispatcher workflows will change dramatically:

• Less emphasis on reactionary responses (putting out the fires) to changes in routes, delays, and NAS impacts.

• More emphasis on thoughtful and robust pre-planning in terms of meeting the business goals for each individual flight in consideration of forecasted and changing NAS constraints.
How will Dispatch systems need to deal with Electronic Negotiation?

- Dispatcher workflows will change dramatically:

- TBO will eventually permit post-departure route flexibility. Remember, this flexibility will be expressed in the TOS that was filed by the dispatcher or crew.

- Dispatcher-cockpit-ANSP datacomm will be a critical part of the process.
Dispatcher workflow: CTOP

Dispatcher identifies flights included in CTOP event and initiates route comparison logic in Flight planning system.

FP system uses all available flight data to calculate and prioritize each route option and presents dispatcher with prioritized route variations according to cost.

Dispatcher analyzes route variations, selects and transmits to TFMS-CTOP in priority order, including relative trajectory cost, notification time, start and end time of desire to accept that route, etc.

TFMS-CTOP rations flights and awards route and/or delay factor, transmits to dispatcher. Dispatcher can either accept award and file route, or resend updated TOS. TOS may be reworked and retransmitted to TFMS anytime before flight plan is filed.

Dispatcher loads flight paperwork for crew and files flight plan. TFMS locks out flight from further route change 45 mins. prior to departure or earlier if lockout specified by dispatcher. CTOP may reallocate TOS award as demand or constraint evolves.

Flight departs on awarded user chosen route, dispatcher provides usual flight following. Airborne TOS updating and awarding future enhancement.
How will Dispatch systems need to deal with Electronic Negotiation?

- ATC coordinator workflows will also change:

- CTOP and future TBO automation will allow for “subbing” in these initiatives, but in different and unique ways from what we do today for GDPs or AFPs.

- Flights can be subbed, but not only is the slot in the constraint swapped, the route may also change depending on what the dispatcher filed in the TOS.

- Operators may also indicate within each TOS a relative inter-flight priority of desire for trajectory “awarded”.
How will Dispatch systems need to deal with Electronic Negotiation?

- ATC coordinator workflows will also change:
- CTOP will reside in FAA TSD, not FSM or any “outboard” automation. Users will not initially have modeling capability.
- CTOP FCA data “may” be available for user viewing in FSM.
- Flight operators may develop procedures and automation for ATC coordinators to “pre-prioritize” flights captured in a particular TMI before dispatchers file their TOS for each flight.
- Subbing flights that transit multiple CTOP FCAs will be challenging.
To sum it all up:

Major paradigms shifts will occur for:

• FP system automation design.

• Dispatcher workflows.

• ATC coordinator workflows.

• Inter-dependent communication workflows between the dispatcher-cockpit-ANSP.
Electronic Negotiation will begin with CTOP next year.

Will you be ready?
CTOP, A Business Aviation Perspective

Thoughts to consider

Presented by:
Ernie Stellings, NBAA
Jim McClay, NBAA

*With data provided by NBAA member Survey
NBAA & CTOP

- How has NBAA been involved?
- Why is NBAA involved in CTOP?
- Importance of participation/Inclusion
- User interface---user friendly as possible
- How do they file their flight plans now?
- How will GA participate?
NBAA & CTOP

How has NBAA been involved in the development of CTOP?

- NBAA has had a presence on the CDM Workgroups for a number of years.
- As CTOP (known as SEVEN at the time) was conceived in the Future Concepts Team (FCT), NBAA was involved in the process.
- Once the SEVEN product was handed off to the Deployment Team, NBAA was asked to participate.
Why is NBAA involved with CTOP?

- CTOP is an important piece of NextGen, which NBAA has a strong commitment to.
- To ensure equitability and access to the CTOP process:
  - Once CTOP comes online, most of the airlines are going to utilize the system.
    - Those operators who do not participate will be at a disadvantage.
  - Participation by everyone is critical to the success of CTOP.
    - If a large segment of civil aviation does not participate in CTOP, the program loses some of its effectiveness.
Types of General Aviation Operators

- Single pilot, files his own flight plan
  - N-registered aircraft
- Small flight department, files their own flight plan
  - Large amount of business aviation falls into this category
- Small flight department, uses FPSP
  - Not a large number due to FPSP cost
- Large flight department, files their own flight plan
  - Another large segment of business aviation
- Large flight department, uses FPSP
  - More large operators use FPSP due to complexity of operation
- Fractional operators, CDM, dispatchers file flight plan
  - These operators have direct access to TFMS
- Fractional and Charter operators, non-CDM, pilots or dispatchers file flight plan
  - Another large segment of business aviation

* FPSP – Flight Plan Service Provider
Types of General Aviation Operators

Flight Planning Methods

• For those filing their own flight plans:
  • Portals used are:
    • FSS
    • DUATS
    • Fltplan.com
  • May have pilots or schedulerdispatcher file

• For those using FPSPs
  • FPSPs may be CDM participants or non-CDM participants
  • Primary interface between FPSP and operation may be either the pilot or the schedulerdispatcher
Types of Flight Plan Entry Points

Methods of entry for GA Flight Plans

• FSS
• DUATS
• Fltplan.com *(CDM member but not providing full FP Services)
• Non-CDM FPSP
  • Example – Jeppesen/Colt *(As of 7/28-Jepp wants to join CDM)
• CDM FPSP
  • Example – Honeywell Flight Sentinel, Air Routing, Arinc Direct, Universal
• CDM Fractional
  • Examples - Netjets, Flexjet, Flight Options
NBAA Flight Planning Survey

To help identify what mechanisms business aviation operators are using to file flight plans, NBAA conducted a survey of its Members.

- There were over 400 participants from within the business aviation community.
- Over 70% of respondents indicated that they utilize a FPSP; most of the remainder use Fltplan.com
  - *Note that most respondents were large flight departments – these numbers are not reflective of all of general aviation*
- Over 90% do not use dispatchers – the pilots do the flight planning
- 85% of respondents file their flight plans more than 2 hours in advance of their flight.
- Over 60% of respondents do not know about reroutes or NAS constraints before filing their flight plan – most find out only after speaking with ATC.
- Most respondents are accessible via mobile devices (Blackberry, iPhone, etc)
The Need for a CTOP Interface for GA

It is clear that a user interface is required to allow general aviation to participate in CTOP

- While the airlines and possibly some of the larger fractional operators will build an interface to CTOP into their own systems, the need for an interface remains for the rest of general aviation.
- We see this need for an interface broken into two groups:
  1. Those who will utilize a cost-based flight plan service provider
     - This group will likely consist of mostly high-end business aviation
     - Examples include Honeywell Flight Sentinel/Air Routing/Arinc
  2. Those who will utilize a low-cost or free flight planning option
     - This group will be comprised of the bulk of general aviation
     - Examples include Fltplan.com/DUATS
The Need for a CTOP Interface for GA

The discussion of this interface is a large part of the reason for this CTOP Industry Day

- *If there are no interfaces available for general aviation/business aviation, there will be no way for our industry to participate in CTOP.*
- *At this time, there are no plans for the FAA to built any type of user interface for industry*
The Need for a CTOP Interface for GA

The requirement for a CTOP user interface provides significant opportunities for service providers

- Once CTOP comes online, service providers that offer the ability for operators to participate will have an advantage over those who do not
  - This allows the opportunity for service providers to distinguish themselves from the competition
- It is going to be in the best interest of the service providers to offer the most user-friendly, cost-effective solution possible.
- There is the opportunity to take advantage of various marketing and pricing models
  - Stand-alone free service, possibly utilizing ad-driven pricing model
  - Integration of CTOP interface with existing service offerings, using low-cost or “almost free” pricing model
  - Integration of CTOP interface into high-end flight planning service, utilizing additional cost on top of existing service
Questions Remaining

There are a number of questions that still need to be. Some of these issues will be covered later today.

- One big one is on the next slide—Connectivity for non-CDM participants—FSS/DUATS, no connectivity to TFMS for TOS submission/award
Connectivity to TFMS

• Current Paths for submission:
  – Non-CDM FPSP-These operators actually feed their customer data to DUATS for entry so they would all be impacted the same way. Even if they created an internal interface, there is no DUATS interface to provide a transfer of information.
  – CDM FPSP-All have AOCNET/VPN connection that allows for them to send CDM (FC/FX, type CDM messages) directly to TFMS. Most file the actual FP through DUATS. They would just need to make the investment in IT to support an interface that meets the ICD.
  – CDM Fractional (Netjets, Flexjet, Flight Options), similar to above, they have existing AOCNET connectivity and would just need to make the investment in IT to support an interface that meets the ICD.
  – Non-CDM Fractional (CitationAir), use a variety of methods including Fltplan.com. A mixed degree of access depending on what they use.
Method to Receive CTOP Award

• How would users Submit or receive CTOP Award/Updates if CTOP began today?:
  – Present day (Fall 2011 Deployment)
    • FSS/DUATS/NonCDM FPSP/NonCDM Fractional—no connectivity to TFMS, no ability to receive or transmit a CTOP Award. These classes have no ability as it stands now, to interface and transmit a TOS, receive a CTOP award and then transmit that award to an operator.
    • CDM FPSP/Fractional-This class of user is connected via AOCNET/VPN and would all have to decide whether or not to build an interface in order to receive CTOP messages and process awards
Questions?
Industry Day Introduction to the Collaborative Trajectory Options Program (CTOP)

Rick Oiesen
13 October 2010
Areas Discussed in this Briefing

I. Overall CTOP Approach and Philosophy
II. Quick Sketch of How CTOP Works
III. Fuller Description of How CTOP Works
IV. Practical Issues with CTOP
V. How the CTOP Algorithm Assigns a Trajectory to a Flight
I. Overall CTOP Approach and Philosophy
The Basic Problem

• Suppose that there is en route congestion.
  – This might be caused by weather, failed navaids, unusually high demand, or any other reason.

• The two general methods that are currently used to hold down en route congestion are:
  – Reroute flights.
  – Delay flights on the ground.

• The essence of the Collaborative Trajectory Options Program (CTOP) is to provide a mix of reroutes and ground delays to deal with the congestion.
Relation of CTOP to Current En Route Tools

- There are two types of Traffic Management Initiatives (TMIs) currently used to deal with en route congestion.
  - Required reroutes: Assign reroutes but not ground delays.
  - Airspace Flow Programs (AFPs): Assign delays but not reroutes.
- CTOP generalizes these two tools by assigning both delays and reroutes.
- CTOP tries to assign a mix of reroutes and delays that:
  - Results in the capacity constraints to be met (keeps FAA happy).
  - Minimizes inconvenience to the NAS users (keeps NAS users happy).
The CTOP Philosophy: Division of Responsibility

• When a reroute is needed, currently the FAA chooses the reroutes for each flight.
• In contrast, the CTOP philosophy is to give the NAS users as much say as possible in the reroute.
  – The FAA specifies the constraints.
  – NAS users submit their route preferences.
  – The CTOP algorithm in the Traffic Flow Management System (TFMS) gives each flight its most preferred trajectory, given the constraints.
CTOP and Electronic Negotiation

• A hallmark of CTOP is that the entire process of determining the routes and delays that are needed to deal with en route congestion is handled electronically.
  – Paper and phone calls are to be avoided.

• This addresses a major current problem, which is that such automated support is lacking in current reroutes.

• In contrast, GDPs make heavy use of electronic messages sent from system to system.
  – Electronic messages include the initial issuance of program, airline substitutions, and new EDCTs due to revisions, Slot Credit Subs or Adaptive Compression,
  – This electronic data exchange allows GDPs work smoothly, and reroutes need the same.
Summary of What is New in CTOP

• A mix of delays and reroutes is assigned.
• Rather than the FAA assigning the routes, the new process gives the NAS users a much bigger role:
  – The FAA specifies the constraints.
  – NAS users submit their route preferences.
  – The FAA then gives each flight its most preferred trajectory, given the constraints.
• Electronic Negotiation.
II. Quick Sketch of How CTOP Works
Quick Sketch of How CTOP Works

1. The Command Center defines the constraint by creating one or more Flow Constrained Areas (FCAs).

2. NAS users send in trajectories they are willing to fly and indicate their preferences.
   - NAS users send trajectories in what is called a Trajectory Option Set (TOS) message.
   - NAS users can send trajectories at any time, and they can send in new trajectories as conditions change and their preferences change.

3. Note: These first two steps can happen in any order.
3. A traffic manager in the Command Center consults with the various stakeholders, defines a CTOP program, and then issues it.

• Sets the CTOP parameters, e.g., capacities for each FCA for each 15-minute interval, start time, stop time.
• Runs the CTOP algorithm to assign routes and delays to each flight in the FCA.
  • The essence: Each flight is given its most preferred trajectory, given the capacity constraints and the other traffic.
• Inspects the modeled results, and, if necessary, modifies the CTOP parameters and re-models.
• When satisfied, issues the CTOP program. This means that the routes and delays for each flight are sent out electronically.
4. Operational personnel execute the program.
   - The ground delays are enforced with EDCTs.
   - The reroutes are enforced as in the current system, that is, the routes assigned by CTOP are treated as required reroutes.

5. NAS users lessen the impact of the CTOP program on them by responding with substitutions and additional TOSs.
Simplified Sketch of How CTOP Works

6. Over time the Command Center revises the CTOP program as necessary.
   • Manually
   • Automatically

7. The capacities can be gradually increased to end a CTOP program.

Note: In the initial release, CTOP will apply only to pre-departure flights.
III. Fuller Description of How CTOP Works
1. The Command Center Defines the Constraint by Creating One or More FCAs

- An FCA is used to control en route congestion.
- Any type of FCA can be used.
  - Line.
  - Polygon.
  - NAS element, e.g., sector or military SUA.
- The FCA is given a start and end time and is filtered as desired, e.g., to include only eastbound flights.
- CTOP allows multiple FCAs to be linked together into a single CTOP program.
2. NAS Users Send in Trajectories

- For each flight, a NAS user has the option of sending a Trajectory Option Set (TOS) to TFMS.
- The key content of a TOS is a series of trajectories for each flight, along with preference information.
- The CTOP trajectory consists of:
  - Wheels-up time.
  - Route of flight in flight plan format.
  - Cruising altitude.
  - Cruising speed.
2. NAS Users Send in Trajectories

• The preferences for each trajectory are expressed by:
  – The Relative Trajectory Cost (RTC) gives the preferences in terms of minutes of ground delay.
    • The RTC, in effect, says how much this trajectory hurts me.
  – The earliest and latest take-off time for which this trajectory is considered feasible.
  – Minimum notification time for a trajectory.
    • For example, if a trajectory requires re-fueling, a NAS user might require at least 45 minutes of notice if it is given this trajectory.
    • If the minimum notification time cannot be given, then this trajectory, in effect, drops out of the TOS.
2. Example of a Trajectory Option Set Message

• The next slide shows an example of the body of a TOS.  
  – The header, which identifies the flight, is omitted.

• The first four fields define the trajectory for a flight.  
  – The desired departure time would be in the header, and here is shown in the body of the TOS for clarity.

• The last four fields are optional fields that allow a NAS user to express its preferences.

• As a NAS user becomes more sophisticated, it can use more of the optional fields to more fully express its preferences.  
  – If all four fields are left blank, CTOP will give the flight the trajectory that provides the smallest delay.
## 2. Example of a Trajectory Option Set (TOS)

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2. How the Relative Trajectory Cost Works

- Suppose that a TOS has two trajectories.
- Trajectory1, which the user prefers, is given an RTC of 0.
- Trajectory2 is given an RTC of 10.
- Suppose the user can take trajectory2 with no delay.
- This means:
  - If the user could take trajectory1 with a ground delay of less than 9 minutes, the user prefers trajectory1.
  - If the user could take trajectory1 with a ground delay of 10 minutes, the user is indifferent between the two trajectories.
  - If the user could only take trajectory1 with a ground delay of more than 10 minutes, then user prefers trajectory2.
2. Explicit v. Implicit Trajectories

- The TOS example shows six explicit trajectories.
- Many trajectories not explicitly shown are implicit in this TOS.
  - For the second trajectory, there is an explicit trajectory with a departure time of 1300.
  - There are implicit trajectories with the same route, altitude, and speed, but with departure times of 1301, 1302, ..., 1459, 1500.
  - So this one line in the TOS provides 1 explicit trajectory and 120 implicit trajectories.
2. Explicit v. Implicit Trajectories (cont.)

• The third line of the TOS gives one explicit trajectory and 180 implicit trajectories.
• All told, the six lines in this TOS provide literally hundreds of trajectories.
• The CTOP algorithm will choose from these hundreds of trajectories the trajectory that the NAS user most prefers that does not cause demand to exceed capacity.
• That this simple TOS can define hundreds of trajectories as well as the preference ordering over them shows the power that this approach puts into the hands of the NAS users.
2. NAS Users Send in Trajectories

• A NAS user can send in the initial TOS for a flight at any time.
  – If there are no CTOP programs in effect, then a TOS serves as an early intent message but plays no other role.

• A NAS user can send in a revised TOS at any time, and the system will immediately take the new trajectories and preferences into account.

• The NAS user decides how many trajectories to put into each TOS.
  – Each NAS user can decide on its desired TOS strategy, e.g., a infrequent TOSs with many trajectories, or frequent TOSs with a few trajectories, or anything else (within certain limits).
2. NAS Users Send in Trajectories

• If the NAS user does not send in an explicit TOS, then the flight plan is used to construct an implicit TOS with only one trajectory.

• The NAS user is required to include at least one trajectory in the TOS than can be assigned an indefinite amount of delay, i.e., has no end time.
  – This is necessary to insure that a solution exists.

• If a TOS contains only one trajectory, the NAS user will get that trajectory for sure, though perhaps with a large delay.
3. Command Center Defines and Issues a CTOP Program

• The traffic manager at the Command Center specifies:
  – One or more FCAs.
  – A time period to be covered.
  – The capacity for each FCA for each fifteen-minute period.
  – Other parameters to be discussed.
3. Very High Level Description of the CTOP Algorithm

- The CTOP algorithm calculates the route and delay to be given to each flight.
  - Exempt flights, e.g., international flights and airborne flights, are given their most desired trajectory.
  - The remaining flights are ordered, speaking generally, on a first-come/first-served basis.
  - The algorithm then proceeds down the list one flight at a time, giving each flight its most preferred trajectory that does not cause capacity to be exceeded, given the demand that has already been assigned.
3. Command Center Defines and Issues a CTOP Program

• The traffic manager can look over the calculated solution, revise the parameters and calculate again, and continue until satisfied.

• When satisfied, the traffic manager issues the CTOP program.
  – The flight assignments are sent out electronically.

• Details to the CTOP algorithm for assigning trajectories are covered later in this briefing.
3. TFMS Sends CTOP data to NAS Users

• NAS Users can register to receive CTOP messages.
  – Similar to unsolicited messages for GDPs and AFPs.

• Message types include:
  – CTOP program data whenever a CTOP program is initiated or modified.
  – Individual flight updates whenever the CTOP assignment for a flight changes for any reason.

• An advisory will be sent only when a CTOP Program is initiated or cancelled, not for every modification.
4. Operational Personnel Execute the CTOP Program: Delays

- Every flight in a CTOP program is required to take off on the departure time that CTOP assigns it (if any).
  - Every flight that will penetrate the CTOP FCA on its assigned TOS option is given an EDCT.
  - If a flight has an EDCT, CTOP requires it to take off on time, even if it is has not been delayed.
  - An EDCT is seen as the way to coordinate all the players to maximize the chance that the flight gets off on time.
4. Operational Personnel Execute the CTOP Program: Reroutes

- Every flight in a CTOP program is required to stay on the route that CTOP assigns it.
  - Conformance with the CTOP route assignment will be monitored and enforced as today with conventional reroutes.

- If more than 45 minutes prior to departure, NAS users are generally expected to file a flight plan that conforms with the CTOP assignment.

- If within 45 minutes of departure, the FAA is expected to amend the flight plan as needed.
5. NAS Users Respond to a CTOP Program

• The NAS users are given various privileges that allow them to manage (though not totally avoid) the impact of a CTOP program on their operations.

• A NAS user can send in new TOSs.
  – A new TOS will completely replace the previous TOS.
  – CTOP will immediately recalculate to reflect the new TOS.
  – The user might send in new TOSs as it thinks of new trajectories or as changing circumstances change its preferences.
5. NAS Users Respond to a CTOP Program

- NAS users can send in substitutions.
  - The general idea is that a NAS user is given a set of slots in a CTOP program, and the user can shuffle its flights among the slots however it wishes.
  - In addition, a NAS user can take a flight out of a CTOP program by routing a flight out of an FCA, thus opening a slot that it can use.

- Example: If UAL has one flight that enters an FCA at 1610 and another at 1640, it can swap those two flights.

- There are many details about how CTOP handles subs. This will be covered in the technical session this afternoon.
6. FAA Revises the CTOP Program

• The traffic manager has two options for revising a CTOP program.
  – Manual: The CTOP trajectory and delay assignments change only if the traffic manager explicitly revises the program.
    • “Dial up” and “dial down” are often used to refer to changing the target capacities.
  – Automatic: The Automatic Revision capability, which is optional, allows CTOP to periodically look for demand and capacity imbalances and to recalculate as necessary. New trajectories and delays are sent out if necessary.
    • This is automatic with no human intervention.
6. How Automatic Revision Works

• The traffic manager sets for each 15-minute interval:
  – The target capacity.
  – An upper trigger value.
  – A lower trigger value.
  – A periodic recheck interval (e.g., 10 minutes)

• Every ten minutes (or whatever the recheck interval is) CTOP looks for intervals where:
  – Demand exceeds capacity by more than the upper trigger value or
  – Demand falls short of capacity by more than the lower trigger value.
6. How Automatic Revision Works

- If CTOP finds an interval where demand departs too much from capacity, it recalculates and automatically sends out the new trajectories and delays.

- Automatic Revision is designed to keep demand close to capacity without imposing undue workload on the traffic manager.
  - If demand gets too high, congestion is threatened.
  - If demand gets too low, capacity is wasted.
7. Capacities Can Be Gradually Increased to End a CTOP Program

- CTOP provides a natural exit strategy.
  - As weather improves, capacities can be gradually raised to the clear-weather value, and CTOP keeps demand matched to the rising capacity.
IV. Practical Issues with CTOP
When Will NAS Users be Ready to Send TOSs?

- To be effective, TOS generation needs to be automated or at least semi-automated.
- It is expected that flight planning systems will need to be modified to generate trajectories for the TOS.
- How long will it take for these modifications to be made to flight planning systems? Or are the capabilities already in place?
- How will the NAS users ramp up their capability?
Is the Proposed Scheme for Representing NAS User Preferences Satisfactory?

• To what degree does the preference data that CTOP allows in a TOS (Relative Trajectory Cost, Minimum Notification Time, start and stop times) provide a NAS user with a satisfactory way to express its preferences? What else if anything is needed to fully express the NAS user’s preferences?

• Does the idea of a NAS user expressing its preferences and then the FAA providing the most preferred alternative work in practice? Or is it too hard for the NAS user to express its preferences in light of the large number of possible trajectories and the unpredictable weather?
V. How the CTOP Algorithm Assigns a Trajectory to a Flight
How the CTOP Algorithm Assigns Trajectories

• You can think of CTOP assigning trajectories to all the flights in a CTOP program in the following way.
  – The algorithm determines the flights in the program.
    • This is the list of flights that might go through the relevant FCAs during the relevant time period.
  – The algorithm orders the flights in the program in a fair way.
    • The order is determined dynamically during the calculation.
    • The rules for ordering the flights are not covered in this briefing.
  – After providing the exempt flights with their most preferred trajectories, the algorithm assigns a trajectory to the first remaining flight, then the second flight, and so on, until all flights have been assigned a trajectory.
    • The trajectory assigned to a flight takes into account the trajectories assigned to previous flights but with no thought of the flights that follow it.
When Does the CTOP Algorithm Assigns Trajectories?

• Cases where CTOP assigns a trajectory to a flight.
  – When a CTOP program is first issued.
  – When a CTOP program is revised manually.
  – When a CTOP program is revised automatically with Automatic Revision.
  – When a new TOS is received when a CTOP is in effect.
  – When there is a pop-up, i.e., when a CTOP is in effect and a new flight appears that was not previously included in the program.

• The trajectory assignment method described in this briefing applies in all of these cases.
The Essence of How CTOP Assigns a Trajectory to a Single Flight

• Pick a trajectory that:
  – Does not cause predicted demand to exceed capacity in any fifteen-minute interval for any controlled FCA in the CTOP program.
  – Does not violate the required minimum notification time specified by the flight operator in the TOS.
  – Does not violate the start and end times specified by the flight operator in the TOS.
  – Minimizes the Adjusted Cost, which is the sum of the Relative Trajectory Cost (RTC) provided by the flight operator in the TOS plus the minutes of ground delay assigned to this flight.
Examples of the CTOP Algorithm at Work

- The following slides give a series of examples that show how the CTOP algorithm chooses a trajectory for a single flight.
- The key equation to remember is
  \[ \text{Adjusted cost} = \text{RTC} + \text{assigned delay}. \]
- Minutes of ground delay is the common currency used to express the cost of a trajectory.
- Acknowledgement: These examples are taken from a MetronAviation briefing.
Example 1: 1 FCA, 1 route

Current Trajectory:
RO1 ETD 14:00z

Slot assigned to this flight in FCA001 at 15:30

Adj. Cost = RTC + Delay Required
Example 2: 1 FCA, Several Routes, No RTC Set

Current Trajectory:
RO3 ETD 14:00z

<table>
<thead>
<tr>
<th>ERTD</th>
<th>RO</th>
<th>RTC</th>
<th>RMNT</th>
<th>TVST</th>
<th>TVET</th>
<th>Delay Required</th>
<th>Adj. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00</td>
<td>RO1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>30+0=30</td>
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<tr>
<td>14:00</td>
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<td>-</td>
<td>-</td>
<td>10</td>
<td>10+0=10</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0+0=0</td>
</tr>
</tbody>
</table>

Flight controlled out of FCA001. No EDCT.
Example 3: 1 FCA, Several Routes, RTC Set

Current Trajectory:
RO2 ETD 15:00z

<table>
<thead>
<tr>
<th>ERTD</th>
<th>RO</th>
<th>RTC</th>
<th>RMNT</th>
<th>TVST</th>
<th>TVET</th>
<th>Delay Required</th>
<th>Adj. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00</td>
<td>RO1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>30+0=30</td>
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<tr>
<td>15:00</td>
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<td>-</td>
<td>-</td>
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<td>40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0+40=40</td>
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</tbody>
</table>
Example 4: Minimum Notification Time

Current Trajectory:
RO2 ETD 15:40z

Current Time: 14:05z

<table>
<thead>
<tr>
<th>ERTD</th>
<th>RO</th>
<th>RTC</th>
<th>RMNT</th>
<th>TVST</th>
<th>TVET</th>
<th>Delay Required</th>
<th>Adj. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:40</td>
<td>RO1</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>65</td>
<td>65+0=65</td>
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<tr>
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<td>RO3</td>
<td>40</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>25</td>
<td>25+40=65</td>
</tr>
</tbody>
</table>
Example 5: Valid Time Ranges

Current Trajectory:
RO2 ETD 15:10z

FCA001
14:00-18:59

Current Trajectory:
RO2 ETD 16:10z

<table>
<thead>
<tr>
<th>ERTD</th>
<th>RO</th>
<th>RTC</th>
<th>RMNT</th>
<th>TVST</th>
<th>TVET</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:10</td>
<td>RO1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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<td>RO2</td>
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<td>-</td>
<td>15:29</td>
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<tr>
<td>14:10</td>
<td>RO2</td>
<td>25</td>
<td>-</td>
<td>15:30</td>
<td>-</td>
</tr>
</tbody>
</table>

Delay Required  Adj. Cost
---  -------------------
80   80+0=80
60   60+15=75

Delay Marked with X
Example 5: User Updates TOS

Current Trajectory:
RO2 ETD 14:00z

<table>
<thead>
<tr>
<th>ERTD</th>
<th>RO</th>
<th>RTC</th>
<th>RMNT</th>
<th>TVST</th>
<th>TVET</th>
<th>Delay Required</th>
<th>Adj. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00</td>
<td>RO1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>30+0=30</td>
</tr>
<tr>
<td>14:00</td>
<td>RO2</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10+15=25</td>
</tr>
</tbody>
</table>

New TOS submitted

<table>
<thead>
<tr>
<th>ERTD</th>
<th>RO</th>
<th>RTC</th>
<th>RMNT</th>
<th>TVST</th>
<th>TVET</th>
<th>Delay Required</th>
<th>Adj. Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00</td>
<td>RO1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>30+0=30</td>
</tr>
<tr>
<td>14:00</td>
<td>RO2</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>10+15=25</td>
</tr>
<tr>
<td>14:00</td>
<td>RO4</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0+20=20</td>
</tr>
</tbody>
</table>
Conclusion

• These examples show how
  – The user preferences stated in the RTC, start time, end time, and minimum notification time…
  – Interact with the available trajectories, which consider the capacities and the demand that has already been assigned…
  – To result in assignment of the trajectory that the user most prefers, given the trajectories that are available.
CTOP ICD and Data Exchange

Ken Howard
13 October 2010

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Introduction

• A draft of the CTOP (nee SEVEN) Interface Control Document (ICD) was distributed for review.

• Since that time, the FAA-industry CTOP Deployment Team has discussed a number of corrections and changes to the ICD.
  – These changes are still being discussed and should not yet considered as final.

• Today’s briefing:
  – Walk through the interface approach in some detail.
  – Highlight changes or additions that are being considered (in blue).
  – Discuss comments and questions from industry.

• Goal is to get as much concurrence and feedback as possible, so please offer your suggestions and criticisms!

• A final ICD will be generated in December.
Scope of CTOP ICD

- Covers CTOP message exchange between automation systems.
  - FAA’s Traffic Flow Management System (TFMS)
- Message exchange includes:
  - FCA Definitions (TFMS -> FOS)
  - TOS submittal (FOS -> TFMS)
  - Issuing CTOP Traffic Management Initiatives (TMI) (TFMS -> FOS)
  - Issuing Trajectory Assignments (TFMS -> FOS)
  - Sending CTOP Substitutions (FOS -> TFMS)
- Does NOT include:
  - Access to modeling tools.
  - Web interfaces.
  - Messages for filing or amending flight plans.
  - CDM messages for creating or modifying basic flight data.
Overview of CTOP Messaging

- FOS sends TOSes to TFMS at any time.
  - Up to the flight operator to figure out how they want to approach this.
  - Number of options per flight will probably be limited for performance reasons.
  - Flight must already exist in TFMS database; from OAG, CDM feed, flight plan.
  - Lowest cost TOS option used for baseline TFMS modeling unless flight plan has been received.

- TFMS sends a CTOP FxA definition whenever created or updated.
  - May be either an FEA or FCA.
    - Actual CTOP TMI can be issued only for FCAs.
    - FEAs may be used for proposed CTOPs.
  - FxAs must be issued prior to the CTOP.
  - FxA definition does not include flight list, but FOS can request a flight list.
  - NOTE: The term is FCA used primarily through the briefing.
Overview of Messaging

• TFMS sends CTOP TMI message when a CTOP is first issued or is revised.
  – This includes the entire set of data for the TMI:
    • Parameters of the CTOP.
    • FCAs controlled by the CTOP.
    • List of flights and their initial trajectory assignments.

• (The remaining messaging occurs once the CTOP is in place.)

• FOS sends substitutions and/or new TOSes at any time, except when a CTOP is being revised by FAA.
  – Successful substitution returns new trajectory assignments.
  – New TOS may or may not trigger a new trajectory assignment.
    • NOTE: Trajectory assignment sent as separate message from reply.
Overview of Messaging

• TFMS sends new trajectory assignments for individual flights whenever changed. This includes:
  – Changes due to automatic revisions.
  – Changes due to new TOS submittals.
  – Trajectory assignments for pop-ups and drop-outs.

• FAA will suspend CTOP processing when in the process of revising a CTOP. During suspension:
  – New TOSes will be queued up and processed when the processing is resumed.
  – Substitutions will be rejected.
  – TFMS will send a message to the FOS when CTOP processing is suspended and resumed; similar to SUB OFF/SUB ON for GDP.
Overview of Messaging

• To execute the negotiated trajectory assignment:
  – Flight operator files flight plan conformant with trajectory assignment.
    • This is done according to normal procedures.
    • Not covered in the ICD.
  – If filed flight plan is not conformant with assigned route, TFMS amends flight plan to be conformant.
    • TFMS will send a message to the FOS when a flight plan is amended.
  – TFMS sends EDCTs to host/tower to implement the assigned departure times.
Protocol

- CTOP messages will use new, dedicated TCP/IP connections.
  - Exception: EDCT updates will also be sent using connections and message formats already in place for GDPs and AFPs.

- FOS is the client.
  - FOS must initiate and maintain the connection.

- Connections can be continuous or temporary.
  - TFMS sends “unsolicited” messages only to active connections.
  - Incumbent on FOS to either maintain connection or recover possible lost data.
  - FOS must ensure that TFMS has current data for its flights.
Typical Continuous Session

- FOS establishes a socket connection.
- FOS identifies itself (Connect message); TFMS checks authorization.
- FOS requests data (FCAs, CTOPs) to synchronize itself with TFMS.
- FOS and TFMS exchange data dynamically through continuous connection.
- FOS sends “heartbeats” to verify connection during periods of inactivity.
- NOTES:
  - This is the only way to know immediately when CTOPs are issued or trajectory assignments are made.
  - This is the recommended approach.
Typical Temporary Session

- FOS establishes a socket connection.
- FOS identifies itself (Connect message); TFMS checks authorization.
- FOS submits a TOS and gets a response.
- FOS asks for a trajectory assignment and gets a response.
- FOS closes the connection.
- NOTES:
  - Possibly useful for a web interface that supports occasional users.
Message Formatting

• Message consists of two parts:
  – Fixed-length binary packet header with message type, length of body to follow.
  – Variable-length message body (optional).

• Body of messages uses XML formatting.
  – This is a move away from the current CDM message format, but towards the end goal of using XML for all messaging.
  – Messages can be very large and complex.
  – Compression will be used for large messages; compression will be indicated in the packet header.
  – This means:
    • CTOP messages are not suitable for routing directly to a printer.
    • ARINC Type B (a.k.a. teletype, ADNS) cannot be used for CTOP.
Data Synchronization

- TFMS provides requests for getting all current CTOP data.
- FOS uses these requests:
  - After crash or other restart.
  - If there is an indication its data is “out-of-synch” with TFMS.
  - To support temporary connections.
- Requests provided:
  - List of current FCAs.
  - Current definition for an FCA.
  - Current flight list for an FCA.
  - Current TOS for a flight.
  - List of current CTOPs.
    - Include suspension status (SUB ON/OFF).
  - Current data for a CTOP (includes flights and trajectory assignments).
  - Current trajectory assignment for an individual flight.
Data Synchronization (cont.)

• There are two embedded data elements that help ensure that certain critical data is “in synch”.

• FxAs (referenced by CTOP TMI):
  – FxA definition includes the time last modified (LASTUPDATE).
  – When TMI issued, TFMS includes FCA ID and LASTUPDATE for each FCA.
  – FOS can check if it has correct definitions for the FCAs.

• TOSes (referenced by Trajectory Assignments):
  – FOS puts a TOS sequence number on each TOS update, as well as a trajectory index on each option.
  – When TFMS sends a trajectory assignment, it includes the TOS sequence number and trajectory indices.
Authorization Checking

• When a connection is established, the IP address and initial handshaking establishes what client the connection is from.
• TFMS configuration parameters control the rights of the client in three ways:
  – What flights they can send TOSes for.
  – What flights they can substitute.
  – What flights they should get data updates for.
• These parameters are similar to existing parameters for GDPs and AFPs, but new, separate parameters will be used for CTOPs.
Flight Identification – Correlation with CDM

- As in the CDM messages, a flight is uniquely identified by:
  - Flight ID (e.g., UAL1234, N123A)
  - Origin (e.g., KBOS)
  - Destination (e.g., KLAX)
  - Initial gate time of departure (IGTD) (e.g., 10/13 1250Z)

- CDM messages and CTOP messages will be correlated using these fields.
- If any of these fields changes, an update must be sent using the normal CDM FM message.

- NOTE:
  - All flight data fields not part of the TOS must be maintained using the CDM messages.
Route Format

• At the first Industry Day for SEVEN, it was requested that routes be expressed in ICAO format rather than the old NAS format.

• Changes for TFMS Release 5 include processing of the ICAO format, but with some limitations:
  – TFMS will accept speed and altitude changes within the route of flight but will not model them.

• This leads to good news and bad news for CTOP:
  – TFMS will accept routes in ICAO format.
  – TFMS will have the same limitation for route modeling.
CTOP Modes and Slot Names

• CTOPs can be issued using two different modes.
  • “Entry Mode” defines the capacity as the number of flights that can cross the FCA per time period (e.g., 60 per hour).
    – Most appropriate for line or fix FCAs.
    – If used for polygons or circles, constraint is applied to the first time a flight crossed the boundary.
    – A slot is instantaneous and are named by the FCA name plus the minute at which the flight should cross: FCA007.201010131745.
  • “Peak Mode” defines the capacity as the peak number of flights that can co-exist inside the FCA at any one time (e.g., 24).
    – Can only be used for FCAs with a volume (e.g., polygons, circles).
    – Dwell time becomes critically important.
    – A slot is therefore a range of times and the name includes the entry and exit times: FCA007.201010131745.201010131758.
“No Slots”

• If a flight has a TOS option that intersects an FCA but is assigned to a different option that does not intersect that FCA, the flight has the property of avoiding that FCA.
• This property can be swapped between flights.
• Originally, we were thinking this would be implied by the absence of a slot for that FCA.
• After working through how substitutions, it appears it should be an explicit attribute that can be assigned to a flight.
• A new slot format will be added to the ICD for the no slots.
• For example: FCA007.NOSLOT.
• This may become more clear during the substitution briefing.
Message Overview: FCA

• Message Types:
  – TFMS to FOS
    • CTOP FCA: Individual FCA definitions as created or modified.
    • FCA Delete: Deletes one FCA.
  – Request/Reply
    • FCA List: List of current CTOP FCAs
    • FCA Re-synch: Definition for one FCA
    • FCA Flight List: Flights in one FCA
Message Overview: FCA (cont.)

- FCA Definition
  - FCA Identification
    - FCA_ID, FCA name, last update time.
    - NOTE: Name can change; use FCA ID for unique identification.
    - Use last update time to be sure you have current definition.
  - Spatial-temporal definition:
    - FCA type (e.g., line, circle, polygon), start time, end time, ceiling, floor, location, direction, speed.
    - Sufficient for drawing the FCA.
  - Flight filters:
    - Departure airports, centers.
    - Arrival airports, centers.
    - Fixes, routes, sectors, centers traversed.
    - Etc.
    - Needed to identify flights included in the FCA.
Sample FCA Message

<FCA>
  <FCA_ID>fca.cdmb.lxpc103.20091107131617</FCA_ID>
  <NAME>FCA007</NAME>
  <DOMAIN>PUBLIC</DOMAIN>
  <LASTUPDATE>20021107101623</LASTUPDATE>
  <REASON>NONE</REASON>
  <TYPE>FCA</TYPE>
  <COLOR_ID>17</COLOR_ID>
  <START>20091107140000</START>
  <END>20091107195959</END>
  <EXTENDED>FALSE</EXTENDED>
  <LOOK_AHEAD>6</LOOK_AHEAD>
  <FSM_ELIGIBLE>TRUE</FSM_ELIGIBLE>
  <CTOP_ELIGIBLE>TRUE</CTOP_ELIGIBLE>
  <POLYGON>
    <CEILING>600</CEILING>
    <FLOOR>240</FLOOR>
    <POINTS>4255N/07633W  4244N/07517W  4203N/07505W</POINTS>
    <DIRECTION>180</DIRECTION>
    <SPEED>5</SPEED>
    <DRAWING>TRUE</DRAWING>
  </POLYGON>
  <PRIMARY_FILTER>
    <CONDITIONS>
      <ANY>
        <DEPARTS_ANY>BOS ZNY</DEPARTS_ANY>
        <TRAVERSE_ANY>WHITE WAVEY</TRAVERSE_ANY>
        <AIRCRAFT_CATEGORY_ANY>J</AIRCRAFT_CATEGORY_ANY>
      </ANY>
    </CONDITIONS>
  </PRIMARY_FILTER>
</FCA>
Message Overview : TOS

- **Message Types:**
  - FOS to TFMS
    - CTOP TOS: Trajectory options for a single flight.
      - Reply indicates whether accepted.
      - Acceptance can be partial.
  - Request/Reply
    - TOS Re-synch: Current TOS in TFMS for one flight.

- **TOS Content**
  - Flight-level data:
    - Flight identification fields.
    - ERTD, TOS Sequence, relative flight priority.
  - Trajectory options:
    - Route, altitude, speed.
    - Relative trajectory cost (RTC), valid start and end times (TVST, TVET), required minimum notification time (RMNT).
    - Probably will be limits on number of options per TOS.
Message Overview: TOS (cont.)

• Notes:
  – Flight must exist in TFMS before TOS will be accepted.
  – Routes must be “parsable” by TFMS.
  – A TOS completely replaces previous data for that flight.
  – Two data fields can be updated from either CDM or TOS:
    • Aircraft Type and ERTD.
  – CDM cancel message (FX) cancels a flight regardless of any TOSes received.
  – TOS used for TFMS demand modeling even if no CTOP is issued:
    • TFMS uses lowest cost option unless flight plan filed.
    • Flight plan route always used for demand modeling if available.
  – If CTOP issued and no TOS was provided, TFMS will assign delay using flight plan, early intent, or historical route (listed in order of precedence).
Sample TOS Message

<TOS>

<ACID>UAL123</ACID>
<ORIG>ORD</ORIG>
<DEST>SFO</DEST>
<IGTD>20100304194500</IGTD>
<TYPE>B757</TYPE>
<ERTD>20100304195700</ERTD>
<REL_FLIGHT_PRIORITY>1</REL_FLIGHT_PRIORITY>

<TRAJ_OPTION_LIST>

<TRAJ_OPTION>

<TRAJ_INDEX>1</TRAJ_INDEX>
ROUTE>ORD DCT IOW J10 OBH DCT EKR DCT DTA DCT RUMPS DCT OAL MOD3 SFO</ROUTE>
<ALT>380</ALT>
<SPEED>433</SPEED>
<REL_TRAJ_COST>0</REL_TRAJ_COST>
<RTE_MIN_NOTIF_TIME>30</RTE_MIN_NOTIF_TIME>

</TRAJ_OPTION>

<TRAJ_OPTION>

<TRAJ_INDEX>2</TRAJ_INDEX>
<TRAJ_VALID_END>20100304210000</TRAJ_VALID_END>
ROUTE>ORD DCT PLL DCT FOD J94 ONL J48 RUMPS DCT OAL MOD3 SFO</ROUTE>
<ALT>390</ALT>
<SPEED>441</SPEED>
<REL_TRAJ_COST>20</REL_TRAJ_COST>
<RTE_MIN_NOTIF_TIME>60</RTE_MIN_NOTIF_TIME>

</TRAJ_OPTION>

</TRAJ_OPTION_LIST>

</TOS>
Message Overview: CTOP TMI

- Message Types:
  - TFMS to FOS
    - CTOP TMI: New or revised TMI.
      - A single program that manages one or more FCAs.
    - Trajectory Assignment: Updates one or more flights.
    - Pop-up: Trajectory assignment for new flight in program.
    - Drop-out: A previously controlled flight leaving the program.
      - All CTOP controls are dropped for this flight; it is no longer part of the CTOP.
    - CTOP Delete: Deletes one TMI.
      - All controls are dropped for all flights for this CTOP.
  - Request/Reply
    - CTOP List: List of current CTOPs.
    - CTOP Re-synch: Full definition for one CTOP.
      - Includes list of flights and initial trajectory assignments.
    - Trajectory Assignment: Current TA for one flight.
Message Overview: CTOP TMI

• TMI Content:
  – TMI-level data:
    • TMI name, rank, automatic revision flag, refresh interval.
    • Exempt criteria: active, international, departure time, origins, destinations, etc.
  – FCA-level data:
    • FCA ID, name, last update time.
    • Allocation mode, smoothing factor, rolling indicator, bin size, capacity, automatic revision triggers.
  – Flight-level data:
    • Flight identification fields.
    • Exempt status.
    • Trajectory assignments (more on next slide).

• NOTES:
  – CTOP message includes all flights that traverse the CTOP FCA(s) on any TOS option; these may not all be controlled by the CTOP!
Message Overview: CTOP TMI/Trajectory Assignment

- Trajectory assignments:
  - Can be sent four ways:
    - As part of a CTOP TMI.
    - For one or more flights in a Trajectory Assignment message.
    - In a Pop-up message.
    - In response to a Substitution request.
  - For each flight, includes:
    - Flight identification fields.
    - Exempt status.
    - Full content of the TOS with feedback.
    - Slot(s) assigned to the flight.
    - Assigned departure time (EDCT) – optional.
    - The assigned TOS option – optional.
Message Overview: CTOP TMI/Trajectory Assignment

• Notes:
  – If a flight is controlled by another TMI (GDP, AFP, CTOP),
    • CTOP does not include an EDCT.
    • CTOP assigns lowest TOS option with the lowest RTC.
    • Flight operator must still file the assigned route.
  – If a flight is controlled by the CTOP but exempt,
    • CTOP assigns EDCT with no delay.
    • CTOP assigns lowest TOS option with the lowest RTC.
    • Flight operator must still file the assigned route.
  – If a flight is controlled by the CTOP but non-exempt,
    • CTOP determines delay and TOS option as described earlier.
    • CTOP includes EDCT unless the assigned TOS option avoids all the FCA(s).
    • CTOP assigns lowest adjusted cost TOS option.
    • Flight operator must file the assigned route.
Message Overview: CTOP TMI/Trajectory Assignment

• Notes:
  – TOS feedback includes:
    • All the original TOS data.
    • Which option is the assigned trajectory.
    • Adjusted cost for each TOS option. (Can compute delay if desired.)
    • FCA(s) for this CTOP intersected by each trajectory.
    • Earliest entry time for this flight for each FCA on this trajectory.
  – If no TOS was submitted, Trajectory Assignment includes the flight plan, early intent, or historical route with an indicator of the source.
  – Feedback and slot assignments will be discussed in more detail during substitution briefing.
Sample CTOP TMI Message (part 1)

```xml
<CTOP_TMI>
  <TMI_NAME>DC_METRO</TMI_NAME>
  <TMI_RANK>1</TMI_RANK>
  <PMNT>30</PMNT>
  <SET_AND_HOLD>TRUE</SET_AND_HOLD>
  <REFRESH_INTERVAL>5</REFRESH_INTERVAL>
  <EXEMPT_CRITERIA>
    <ACTIVE>TRUE</ACTIVE>
    <INTERNATIONAL>TRUE</INTERNATIONAL>
    <ARRIVES_ANY>ZNY ZDC BOS</ARRIVES_ANY>
  </EXEMPT_CRITERIA>
  <FCA_LIST>
    <FCA>
      <FCA_ID>fca.cdmb.lxpc103.20100713161706</FCA_ID>
      <FCA_NAME>FCA007</FCA_NAME>
      <LASTUPDATE>20100713161706</LASTUPDATE>
      <FCA_ALLOC_MODE>ENTRY</FCA_ALLOC_MODE>
      <SMOOTHING_FACTOR>3</SMOOTHING_FACTOR>
      <ROLLING>FALSE</ROLLING>
      <FCA_BIN_SIZE>15</FCA_BIN_SIZE>
      <FCA_BIN>
        <FCA_BIN_TIME>20100713150000</FCA_BIN_TIME>
        <FCA_BIN_CAPACITY>20</FCA_BIN_CAPACITY>
        <CONTROLLED>TRUE</CONTROLLED>
        <SET_AND_HOLD>TRUE</SET_AND_HOLD>
        <FCA_BIN_TRIGGER>4</FCA_BIN_TRIGGER>
      </FCA_BIN>
    </FCA>
    ...
  </FCA_LIST>
</CTOP_TMI>
```
Sample CTOP TMI Message (Part 2)

```xml
<FLIGHT_LIST>
  <FLIGHT>
    <ACID>UAL123</ACID>
    <ORIG>ORD</ORIG>
    <DEST>SFO</DEST>
    <IGTD>20100713134500</IGTD>
    <TOS_SEQ_NO>1</TOS_SEQ_NO>
    <ERTD>20100713135300</ERTD>
    <CTD>20100713151000</CTD>
    <SLOT_LIST>
      <SLOT>FCA007.20100713161700A</SLOT>
    </SLOT_LIST>
    <TRAJ_OPTION_LIST>
      <TRAJ_OPTION>
        <TRAJ_INDEX>1</TRAJ_INDEX>
        <ROUTE>PLL FOD J94 ONL J48 RUMPS OAL MOD3</ROUTE>
        <ALT>F390</ALT>
        <SPEED>N0441</SPEED>
        <REL_TRAJ_COST>0</REL_TRAJ_COST>
        <ASSIGNED>TRUE</ASSIGNED>
        <ADJUSTED_COST>37</ADJUSTED_COST>
        <FCA_LIST>
          <FCA>
            <FCA_NAME>FCA007</FCA_NAME>
            <FCA_EARLIEST_ENTRY>20100713150300</FCA_EARLIEST_ENTRY>
          </FCA>
        </FCA_LIST>
      </TRAJ_OPTION>
    </TRAJ_OPTION_LIST>
  </FLIGHT>
</FLIGHT_LIST>
```

Message Overview: CTOP Drop Out/CTOP Delete

• CTOP Drop Out Message content:
  – Flight-level data.
    • Flight identification fields.
    • TOS sequence number, TMI Name.

• CTOP Delete Message content:
  – TMI Name

• Question:
  – When a CTOP is Deleted, does the flight operator expect to get a CTOP Drop Out message for every flight that was formerly controlled by that CTOP?
  – If so, may modify Drop Out format to allow multiple flights.
Message Overview: Substitutions

- **Message Types:**
  - FOS to TFMS
    - Substitution: Set of flights with new slot assignments.
      - Reply indicates whether accepted.
      - Acceptance CANNOT be partial.

- **Substitution Message Content**
  - TMI Name, sub mode.
  - Flight-level data:
    - Flight identification data
    - Slot(s)

- **Notes:**
  - Substitution is successful if TFMS can determine a set of trajectory assignments that allow all of the flights in the message to use all of their assigned slots (sort of).
  - A good response is a new set of trajectory assignments for these flights.
Sample Substitution Message

```xml
<CTOP_SUB_REQ>
  <TMI_NAME>DC_METRO</TMI_NAME>
  <CTOP_SUB_MODE>STRICT</CTOP_SUB_MODE>
  <FLIGHT_LIST>
    <FLIGHT>
      <ACID>UAL123</ACID>
      <ORIG>ORD</ORIG>
      <DEST>SFO</DEST>
      <IGTD>20100713134500</IGTD>
      <SLOT_LIST>
        <SLOT>FCA007.20100713161700A</SLOT>
      </SLOT_LIST>
    </FLIGHT>
    <FLIGHT>
      <ACID>UAL456</ACID>
      <ORIG>ORD</ORIG>
      <DEST>SFO</DEST>
      <IGTD>20100713144500</IGTD>
      <SLOT_LIST>
        <SLOT>FCA007.20100713161700A</SLOT>
      </SLOT_LIST>
    </FLIGHT>
  </FLIGHT_LIST>
</CTOP_SUB_REQ>
```
Questions?
CTOP Substitutions

Ken Howard
13 October 2010

Serving the Nation as a leader in global transportation innovation since 1970
What are Substitutions?

• There is a basic division of responsibility in managing a TMI:
  – FAA determines what slots are given to each operator and makes initial allocation of flights to slots.
  – Flight operator can then modify which flights use which slots.
• What makes this work is that:
  – The subs do not change the demand with respect to the constraints.
  – One operators subs do not affect another’s flights.
• Substitutions (a.k.a., subbing, swaps, trades) is the mechanism for the flight operator to change its slot assignments.
• Subbing is a critical component of GDPs and AFPs, and thus will also be provided for CTOP.
• Subbing for CTOP is very different from GDP/AFP subbing.
Why Do We Need Subbing in CTOP?

• If TOSes perfectly express preferences for route/delay trade-offs and also flight priorities, why do we need subs?
• Answer: The TOS expresses a flight operator’s preferences with respect to an individual flight, while subs express an aggregate set of preferences for a group of flights.
• Consider an example:
  – A flight has two trajectory options, a shorter route option through an FCA and a longer option around the FCA. The longer option has an RTC of 35 minutes.
  – The CTOP assigns the shorter route and a 30-minute ground delay.
  – This is the right decision when considering this flight by itself.
Why Do We Need Subbing in CTOP? (cont.)

- However, that might not be the flight operator’s only flight in the CTOP.
- For example,
  - Assume the flight operator has 10 other flights in the CTOP, each of which received a route through the FCA and 30-minutes of delay.
  - By routing the first flight out of the FCA, the flight operator might be able to eliminate the delay on all 11 of these flights.
  - The flight operator is now balancing the cost of rerouting one flight (worth 30 minutes of ground delay) with the benefit of reducing delays on all 11 flights (up to 330 minutes).
  - There is no way to know this trade-off ahead of time and represent it in your TOS! It is only known after the CTOP is issued. It can only be addressed through subbing.
How Are Subs Typically Used?

• Incidental delays:
  – A flight is assigned a slot at 2315Z, then has a mechanical delay and cannot arrive until 0030Z.
  – User can move other flights earlier to take advantage of the 2315 slot and re-assign the delayed flight to a slot closer to 0030Z.

• Resolving critical issues:
  – A GDP delay is going to cause 6 international connections to be missed.
  – Crew legalities

• Strategic cancellation or reroutes to reduce net cost of the program:
  – See previous example.
Subbing in CTOP

• There are two types of subbing in CTOP, implicit and explicit.
• Implicit subs:
  – Flight operator provides relative flight priorities to TFMS as part of the TOSes.
  – The CTOP algorithm tries to accommodate these priorities every time it runs an allocation by swapping flights and slots.
• Explicit subs:
  – After the CTOP is issued, the flight operator has a set of controlled flights and a set of slots.
  – Flight operator submits messages explicitly re-assigning flights to slots.
• Both are presented in more detail.
Important Concept: Schedule Tokens

- A core aspect of the CTOP algorithm is the schedule token.
- The schedule token determines, in large part, the order in which the flights are allocated to the available capacity.
  - The schedule token is the basis for determining what capacity is allocated to each flight operator.
  - The schedule token is to the CTOP algorithm as the Initial Gate Time of Arrival (IGTA) is to the GDP ration-by-schedule (RBS) algorithm.
- A flight has a schedule token for each CTOP FCA that is intersected by any TOS option for that flight.
  - The schedule token is computed the first time a flight intersects the FCA.
  - The schedule token is the earliest time the flight could intersect the FCA if it departed at its IGTD.
    - That is, if the flight followed its fastest TOS option to that FCA.
- Once a schedule token is computed, it never changes.
CTOP Implicit Subs
Overview of Implicit Subs

• Implicit subs are a way for the CTOP algorithm to take a flight operator’s relative flight priorities (RFPs) into account when computing a CTOP.

• General idea:
  – First, the general allocation algorithm is run for all flights and all slots using schedule tokens.
    • This determines which slots belong to which flight operators.
  – Then, implicit subs looks at each flight operator’s flight and slots and reorders the flights in those slots based on the flight operator-provided RFPs.
  – Loosely analogous to the two-part RBS++ algorithm for GDPs.
How Are RFPs Submitted?

• Implicit subs are optional:
  – A flight operator can choose to send no RFPs and exempt themselves from implicit subbing.
  – A flight operator can choose to send RFPs for its flights and exercise implicit subbing.

• Users set RFPs on their TOS messages.

• RFPs defined as follows:
  – Numeric values; can range from 1 to 999.
  – 1 is highest priority.
  – Not required to be unique.
    • For example, could rate every flight from 1 to 5.
When Do Implicit Subs Run?

- Implicit subs are applied every time a CTOP is computed.
  - This applies to all allocations including automatic revisions.
- A separate implicit sub re-allocation is made for each flight operator that has flights with RFPs in the CTOP.
- Since each implicit sub re-allocation runs on only the flights and slots belonging to one flight operator’s flights, they can be run in any order.
How Do Implicit Subs Work?

• Put the slots initially allocated to the flight operator into a pool.
• Re-allocate that flight operator’s flights to the slots using the implicit sub allocation algorithm.
• The implicit sub allocation is just like the regular allocation except it sorts flights by RFP before sorting by schedule token.

• Following is an example using UAL.
Implicit Sub Example –
One FCA, No route-outs, UAL sent RFPs

<table>
<thead>
<tr>
<th>Flight</th>
<th>RFP</th>
<th>Initial Slot</th>
<th>Final Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAL1</td>
<td>3</td>
<td>16:30</td>
<td>17:00</td>
</tr>
<tr>
<td>UAL2</td>
<td>5</td>
<td>17:00</td>
<td>16:30</td>
</tr>
<tr>
<td>UAL3</td>
<td>2</td>
<td>17:00</td>
<td>17:30</td>
</tr>
<tr>
<td>UAL4</td>
<td>5</td>
<td>17:00</td>
<td>17:00</td>
</tr>
<tr>
<td>UAL5</td>
<td>4</td>
<td>17:30</td>
<td>18:30</td>
</tr>
<tr>
<td>UAL6</td>
<td>2</td>
<td>18:30</td>
<td>17:00</td>
</tr>
<tr>
<td>UAL7</td>
<td>3</td>
<td>18:30</td>
<td>18:30</td>
</tr>
<tr>
<td>UAL8</td>
<td>1</td>
<td>19:00</td>
<td>19:00</td>
</tr>
<tr>
<td>UAL9</td>
<td>4</td>
<td>19:00</td>
<td>19:00</td>
</tr>
<tr>
<td>UAL10</td>
<td>3</td>
<td>19:00</td>
<td>19:00</td>
</tr>
<tr>
<td>UAL11</td>
<td>5</td>
<td>19:00</td>
<td>19:00</td>
</tr>
<tr>
<td>UAL12</td>
<td>5</td>
<td>19:00</td>
<td>19:00</td>
</tr>
<tr>
<td>UAL13</td>
<td>3</td>
<td>19:00</td>
<td>19:00</td>
</tr>
</tbody>
</table>

Exempt flights
Place in bin reserved for exempt flight
Non-exempt, non-UAL flights
Non-exempt UAL flights
Program time period
Flight re-allocated for UAL
Implicit Subs Notes

• What if flight operator sends RFPs for only some of its flights?
  – Only apply implicit subs to flights that have RFPs.

• What flights are grouped together for implicit subs?
  – Any flight that flight operator is authorized to sub for.

• User could “lose” slots.
  – In a more complex scenario with trajectory options, you might get to a point where you have one or more slots left and no flight(s) that can use them.
  – We don’t see any easy way for the algorithm to prevent this.
  – How often might this happen?
  – Are flight operators willing to take this risk?
Implicit Subs in Peak Mode

• In entry mode, all slots are the same size and all flights are interchangeable.
• How do implicit subs work in peak mode, where flights have different dwell times and “super-slots” are different sizes?
  – If you require exact matches, it is likely to inhibit many swaps from happening.
  – If you allow a flight to swap into a larger slot than it needs, you will end up with flights that cannot use the remaining slots.
    • For example, if you swap an 8-minute flight into a 10-minute slot, the 10-minute flight cannot use the now-open 8-minute slot.
  – Would it work to allow flights to swap with an equal +/- tolerance?
    • For example, if tolerance is +/- 2, the above example would be allowed.
    • This is the leading candidate at the moment.
Enhanced Feedback for Implicit Subs

- When a TMI is issued, the messages sent to the flight operators are intended to provide enough information to understand what a trajectory option was assigned and what your options are.
- What feedback would help the flight operators understand how implicit subs affected a flight?
  - Flag indicating a flight was moved by an implicit sub?
  - Original trajectory assignment: TO and CTD?
  - Original adjusted cost? For all TOs?
  - Original slot(s)?
CTOP Explicit Subs
Introduction to Explicit Subbing

- CTOP explicit subbing has some similarities to GDP/AFP subbing:
  - Users are given slots and can swap their flights among those slots.
  - Users must preserve the one-flight-one-slot rule.
  - As long as flight operators preserve the one-flight-one-slot rule, the FAA doesn’t care what flights are in what slots.
  - User can sub flights whenever they want.
  - User can sub flights as often as they want.
  - Authorization checking works the same.
Introduction to Explicit Subbing

• However, CTOP introduces significant new issues and requirements:
  – A CTOP can include multiple FCAs. Therefore,
    • A flight might intersect no, one, or multiple FCAs.
    • A flight might have no, one, or multiple slots.
  – Flights can have multiple trajectory options, each of which might intersect no, one, or multiple FCAs.
  – When you sub, you may not only be changing the times a flight will operate, you may be changing the route.
  – In peak mode, it matters not only when a flight enters an FCA, but how long it is in the FCA.
    • That is, all flights no longer place the same demand on the resources.
How Explicit Subbing Works

• When CTOP is issued, TFMS sends each flight operator a list of its flights (CTOP flight list), and for each flight:
  – Trajectory assignment.
  – EDCT (optional, as flight might avoid all the FCAs).
  – A slot for each FCA intersected by the assigned route, and
  – A NOSLOT for each FCA intersected by a non-assigned route but not the assigned route.

• User can at any time submit a sub request re-assigning any number of flights to their slots.
  – NOSLOTS are available for subbing just like regular slots.
  – You can sub some of a flight’s slots but not others.
  – Flights can own slots they are not currently using.
  – You can use strict or flexible mode (more on this later).
How Explicit Subbing Works (cont.)

- TFMS validates the request:
  - The set of flights must already own the set of slots (like GDP).
  - One-flight-one-slot rules must be preserved (like GDP).
    - Rule is applied per FCA.
  - At least one trajectory (route and departure time) must exist for each flight that allows it to use its assigned slot(s) or NOSLOT(s).

- If request is valid, TFMS:
  - Determines, for each flight, the lowest cost trajectory option that allows the flight to use its new slot (or NOSLOT) assignment.
  - Determines the new EDCTs required for flights to hit the slot times on their new trajectory options.
  - Sends the new trajectory assignments and EDCTs back to the flight operator as part of the substitution reply.
### Explicit Subbing Example 1

**Initial Assignment:**

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1</td>
<td>1715</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2</td>
<td>1745</td>
</tr>
</tbody>
</table>

**Requested sub:**

```
Flight  Slot
Flt 1    1745
Flt 2    1715
```

**Response:**

```
Flight  TO  Slot
Flt 1    1    1745
Flt 2    2    1715
```
Explicit Subbing Example 2

Initial Assignment:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-2</td>
<td>1715</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-2</td>
<td>NOSLOT</td>
</tr>
</tbody>
</table>

Requested sub:

<table>
<thead>
<tr>
<th>Flight</th>
<th>Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>1715</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-1</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-1</td>
<td>1715</td>
</tr>
</tbody>
</table>

“No-slots” can be traded just like slots. TFMS checks for valid trajectories. TFMS will determine new trajectory assignments.
Explicit Subbing Example 3

Initial Assignment:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-2</td>
<td>1715</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-2</td>
<td>NOSLOT</td>
<td>1800</td>
</tr>
</tbody>
</table>

Requested sub:

<table>
<thead>
<tr>
<th>Flight</th>
<th>FCA1 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>1715</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-1</td>
<td>NOSLOT</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-1</td>
<td>1715</td>
<td>1800</td>
</tr>
</tbody>
</table>

Slots are specific to FCAs and can be traded independently.

TFMS checks for valid trajectories.

Flights can own slots they are not currently using.
**Explicit Subbing Example 4**

**Initial Assignment:**

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-2</td>
<td>1715</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-2</td>
<td>NOSLOT</td>
<td>1800</td>
</tr>
<tr>
<td>Flt 3</td>
<td>3-1</td>
<td>NOSLOT</td>
<td>1830</td>
</tr>
</tbody>
</table>

**Requested sub:**

<table>
<thead>
<tr>
<th>Flight</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>NOSLOT</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>1715</td>
<td>1830</td>
</tr>
<tr>
<td>Flt 3</td>
<td>NOSLOT</td>
<td>1800</td>
</tr>
</tbody>
</table>

This sub would be rejected with strict subs, as there is no single trajectory that uses the Flt 2 slots. However, it would be accepted with *flexible subs*. 
Types of Explicit Subs

- CTOP provides two types of subs, strict and flexible, to help the flight operator to get subs accepted.
  - If request is for strict processing, TFMS requires that every flight be able to use every slot exactly as requested.
  - If request is for flexible processing, TFMS goes beyond the strict processing to see if an option exists that may not use the slots exactly as requested, but doesn’t violate the constraint.
    - That is, a trajectory is valid with respect to an FCA if it uses the assigned slot for that FCA or avoids that FCA.

- See examples on next slides.
Example 4 – Flexible Mode

Initial Assignment:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO 1-1</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-2</td>
<td>1715</td>
<td></td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-2</td>
<td>NOSLOT</td>
<td>1800</td>
</tr>
<tr>
<td>Flt 3</td>
<td>3-1</td>
<td></td>
<td>1830</td>
</tr>
</tbody>
</table>

Requested sub:

<table>
<thead>
<tr>
<th>Flight</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>NOSLOT</td>
<td></td>
</tr>
<tr>
<td>Flt 2</td>
<td>1715</td>
<td>1830</td>
</tr>
<tr>
<td>Flt 3</td>
<td></td>
<td>1800</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO 1-1</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-1</td>
<td>NOSLOT</td>
<td></td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-1</td>
<td>1715</td>
<td>1830</td>
</tr>
<tr>
<td>Flt 3</td>
<td>3-1</td>
<td></td>
<td>1800</td>
</tr>
</tbody>
</table>

TFMS picks lowest adjusted cost TOS option for Flt 2.
Example 5 – Flexible Mode

Initial Assignment:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-2</td>
<td>1715</td>
<td>1743</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-3</td>
<td>NOSLOT</td>
<td>NOSLOT</td>
</tr>
</tbody>
</table>

Requested sub:

<table>
<thead>
<tr>
<th>Flight</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>NOSLOT</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>1715</td>
<td>1743</td>
</tr>
</tbody>
</table>

Flexible response:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-1</td>
<td>NOSLOT</td>
<td>NOSLOT</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-2</td>
<td>1715</td>
<td>1743</td>
</tr>
</tbody>
</table>

Both TO 2-2 and TO 2-3 could be used with flexible subs.
How Do I Know My Sub Options?

• To generate a successful sub, the flight operator would want to know:
  – What flights have the option of using what slots?
  – Are there route options that intersect those FCAs?
  – Can a flight arrive in time to hit the slot time?
  – What would be the cost of using a different slot?

• These are things that cannot be easily determined by external systems.

• To facilitate the development of substitution tools, TFMS will provide this data when a CTOP is issued and maintain this data as the program evolves.
How Do I Know My Sub Options? (cont.)

• When a CTOP is issued, the flight operator will get a list of all their flights in the TMI with the following data:
  – EDCT
  – Slot assignments
  – For each trajectory option in the current TOS,
    • Whether it is the assigned trajectory
    • The FCAs intersected by the trajectory
    • The earliest time the flight would intersect that FCA on that trajectory
    • The compute the adjusted trajectory cost.
    • The RTC
      – NOTE: The prior two items allow you to delay would CTOP did assign or would have assigned.
• This data is updated any time it is changed.
• The flight operator can request this data at any time.
### How Do I Know My Options Example

Trajectory Assignment for Flt 1:
TO = 1-2, CTD (EDCT) = 1655, FCA1 Slot = 1743, FCA2 Slot = NOSLOT

<table>
<thead>
<tr>
<th>TO</th>
<th>Assigned?</th>
<th>RTC</th>
<th>Adj Cost</th>
<th>FCA1 Intersection/ERTA</th>
<th>FCA2 Intersection/ERTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>No</td>
<td>20</td>
<td>20</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>1-2</td>
<td>Yes</td>
<td>0</td>
<td>15</td>
<td>1728</td>
<td>no</td>
</tr>
<tr>
<td>1-3</td>
<td>No</td>
<td>30</td>
<td>35</td>
<td>no</td>
<td>1735</td>
</tr>
</tbody>
</table>
Preserving the Order of the Flights

• Issue: If a flight operator uses subs to change the order of its flights, what prevents the next automatic revision from putting the flights right back where they were?

• Answer: CTOP swaps schedule tokens whenever it swaps slots.
  – The thinking is that changing the order of the flights will preserve the intent of the sub.
Preserving Slots Example

Initial Assignment:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-2</td>
<td>1715</td>
<td>No-slot</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-2</td>
<td>No-slot</td>
<td>1745</td>
</tr>
</tbody>
</table>

Requested sub:

<table>
<thead>
<tr>
<th>Flight</th>
<th>FCA1 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>No-slot</td>
</tr>
<tr>
<td>Flt 2</td>
<td>1715</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Slot</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-1</td>
<td>No-slot</td>
<td>No-slot</td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-1</td>
<td>1715</td>
<td>1745</td>
</tr>
</tbody>
</table>
## Preserving Slots Example

### Initial Assignment:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO 1-1</th>
<th>FCA1 Schedule Token</th>
<th>FCA1 Slot</th>
<th>TO 1-2</th>
<th>FCA2 Schedule Token</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>FCA1</td>
<td>1708</td>
<td>No-slot</td>
<td>FCA2</td>
<td>1710</td>
<td>1745</td>
</tr>
<tr>
<td>Flt 2</td>
<td>FCA1</td>
<td>1645</td>
<td>1715</td>
<td>FCA2</td>
<td>1710</td>
<td>1745</td>
</tr>
</tbody>
</table>

### After Sub:

<table>
<thead>
<tr>
<th>Flight</th>
<th>TO</th>
<th>FCA1 Schedule Token</th>
<th>FCA1 Slot</th>
<th>FCA2 Schedule Token</th>
<th>FCA2 Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flt 1</td>
<td>1-1</td>
<td>1708</td>
<td>No-slot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flt 2</td>
<td>2-1</td>
<td>1645</td>
<td>1715</td>
<td>1710</td>
<td>1745</td>
</tr>
</tbody>
</table>
Preserving the Order of the Flights

• Will this always work?
  – It probably depends on the scenario.
  – It might be necessary or advantageous for the flight operator to update TOSes in some cases when subs are submitted to better preserve the changes.
Subbing in Peak Mode

• Remember, in peak mode, slots are not the same size and flights need different dwell times.
• Rules for subbing super-slots:
  – A flight can only be subbed into a super-slot if its dwell time is equal to or smaller than the slot size.
    • For example, you can sub an 8 minute flight into an 11 minute super-slot.
  – Super-slots have to be kept intact.
    • Necessary to preserve the one slot, one schedule token relationship.
    • For example, if a flight is assigned the slot:
      – FCAA01.271801.271823
    • You cannot submit a sub giving two flights the slots:
      – FCAA01.271801.271812
      – FCAA01.271813.271823
Subbing Flexibility

• CTOP provides flexibility in both peak mode and entry mode.
• In entry mode:
  – You can sub a flight into a slot if it can enter the FCA within a +/- tolerance of the slot time.
• In peak mode:
  – You can sub a flight into a slot if it can enter the FCA within a +/- tolerance of the slot time and has a dwell time within a different +/- tolerance of the slot size.
Cancelled Flights

- There are no provisions for cancelled flights in CTOP.
  - They don’t appear in flight list either before or after CTOP issued.
  - If flight has a CTOP slot and is cancelled, the flight drops from the flight list and its slot goes way.
  - That capacity is recovered only if a re-computation is performed, either manually or by automatic revision.
  - The flight operator who cancelled the flight gets no preference for using that newly available capacity.
  - The only option for the flight operator is to sub a flight to as bad a position as possible before cancelling it.
Drop Outs

• A route-out is a flight that changes its route(s) such that it no longer appears in the TMI.
  – For CTOP, this means updating the TOS such that no TOS option intersects any FCA in that CTOP.

• In CTOP, a route-out is treated just like a cancelled flight.
  – The slot goes away.
  – No immediate attempt is made to move any flights earlier, let alone flights for the slot owner.
  – Capacity is recovered in next re-allocation.
  – No credit is given to the flight operator.
Pop-ups

- A pop-up is a flight that appears in a TMI after it has been issued.
- For CTOP, pop-ups are specific to an FCA rather than a TMI.
  - For example, a TMI controls FCA1 and FCA2.
  - A flight is part of the original flight list for FCA1 but not FCA2.
  - If the flight submits a new TOS that intersects FCA2, it is a pop-up for FCA2 but not for FCA1.
- Pop-ups are discouraged by adding a factor to the schedule token, giving it a lower priority than other flights wanting to operate at the same time.
  - This penalty applied only when lead time is short enough.
- When a pop-up first appears, it does not get a slot and cannot be subbed.
- When the next revision is run, pop-ups are processed like any other flights and can be subbed like any other flight.
TOS Updates

• When a TOS is updated for a flight, TFMS computes a new trajectory assignment for that flight.
• However, the slots owned by this flight do not change.
  – That is, you may well have slots assigned to this flight that it is not using.
• The flight operator can use such a flight in substitutions.
  – If the unused slots are earlier than the flight can no use, it may be that it is to the flight operators advantage to move another flight into those slots.
  – This is roughly analogous to a flight in a GDP that has a mechanical delay, and using that flight’s slot to reduce delay on some other flight.
• When the next revision is run, TFMS will assign new slots to all flights that are aligned with the assigned trajectories.
Locking in Delay (ERTD/ERTA)

• Sometimes it is desirable to “lock in” some or all of your assigned delay.

• Example:
  – GDP is issued giving a flight an hour delay.
  – User sees another flight, not in GDP, delayed due to a late aircraft.
  – User swaps the aircraft from the GDP flight to the other flight to make it on time.
  – User sends new ERTD or ERTA stating earliest time the GDP flight can now depart or arrive.

• You can do the same thing for a CTOP but only using the ERTD field.

• You can also lock in your route by updating your TOS.
Interaction of Implicit and Explicit Subs

- Implicit subs could un-do explicit subs.
  - An explicit sub swaps schedule tokens but not RFPs.
  - Swapping schedule tokens “preserves” the explicit sub for the main allocation algorithm.
  - But implicit subs could reverse the effect of the explicit sub.
  - Do flight operators want to mix explicit and implicit subs?
  - Can flight operators manage this by manipulating their RFPs?
Questions?
CTOP Connectivity to TFMS To Support the CDM Community

October 13, 2010
CTOP Connectivity – Provided over current CDM user networks

- CDM users will use existing CDM network infrastructure to TFMS to send TOSs to TFMS and receive CTOP TMI messages back from TFMS
- Socket connection is defined for the session to pass data (XML data packages)
  - ARINC ADNS (teletype) is not an option to support CTOP message exchanges using this approach

CDM Customer Locations
Flight Operator Systems

TPC Operational System

CDM Service Sessions
- ADL Sessions
- Flight Data Sessions
- Substitution Sessions
- CTOP Sessions (NEW)

AOCNET Network
VPN over the Internet

NESG Gateway
*Security Perimeter for all FAA systems

The ICD defines the data exchange between the CDM Flight Operator Systems and TFMS
CDM Connectivity – Current Service Sessions

- CDM Participants utilize application sessions between the CDM Flight Operator Systems and the TFMS TPC
  - In each session, the application running at the CDM user site is considered the client and the application running at the TFMS is considered the server.
- A CDM client process initiates the session by opening the socket connection to a server process using a designated IP address and port.
- Data is exchanged between the client and server during the session connection
  - Client identification is checked and authorized by the server before CDM data is exchanged
  - Either the client or server terminates the session and closes the connection.
- In support of CDM data exchange, three types of sessions are provided
  - Aggregate Demand List (ADL) Sessions
  - Flight Data (FD) Sessions
  - Simplified Substitution (SS) Sessions
  - **CTOP Sessions (New)**

CTOP will be added as the 4th CDM Session Type following the connectivity model for current sessions
CDM Connectivity – CTOP will be the 4\textsuperscript{th} Service Session Type

- **CDM/FOS interface to be implemented as a 4\textsuperscript{th} session type in the CDM/TFMM ICD**
  - Separate TCP Socket connection by CDM client using same registration protocol as other sessions. Port numbers have not yet been defined
  - Dedicated CTOP message exchange with Flight Operator Systems (FOS) is defined in the ICD

- **Rationale for this approach**
  - Separate sessions keeps CTOP messages isolated from other CDM messages.
  - Separate session permits existing services not to be affected. Limits the impact to CDM customers in the re-tooling of current interfaces and software.
  - Enables migration of CTOP tools and procedure with current tool sets without impacting the connectivity and configuration of existing tools
  - Current use of FSM tools and substitution tools can operate with no impact to current connections
Security Considerations for the CTOP Session

• Similar rules as today will apply to the CTOP connection session

• **Authentication:**
  – CTOP messages use the existing CDM interface authentication framework and are implemented as a 4th session using a dedicated socket
  – The connection to the new socket will be governed by access rules at the network layer
  – The connection to the socket will also be authorized via registration rules; a check will be made at the software level to determine if the IP address is for that CDM user

• **Authorization:**
  – CTOP messages utilize a separate set of authorization profiles from other CDM messages
  – Allows a different profile for sub-carrier authorizations to send CTOP messages than for other CDM messages (FC, FM, SCS, etc.)
  – CTOP authorization profiles are maintained as part of TFMS adaptation
## Major CTOP Messages With Estimated Sizes

<table>
<thead>
<tr>
<th>Message Type</th>
<th>Message Name</th>
<th>Originator</th>
<th>Low (bytes)</th>
<th>High (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CTOP FCA Message</strong></td>
<td>CTOP FCA</td>
<td>TFMS</td>
<td>1,800</td>
<td>2,400</td>
</tr>
<tr>
<td></td>
<td>FCA List Request</td>
<td>FOS</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td></td>
<td>FCA List Reply</td>
<td>TFMS</td>
<td>2,800</td>
<td>10,600</td>
</tr>
<tr>
<td></td>
<td>FCA Re-synch Request</td>
<td>FOS</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>FCA Re-synch Reply</td>
<td>TFMS</td>
<td>1,800</td>
<td>2,400</td>
</tr>
<tr>
<td></td>
<td>FCA Flight List Request</td>
<td>FOS</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>FCA Flight List Reply</td>
<td>TFMS</td>
<td>3,000</td>
<td>8,700</td>
</tr>
<tr>
<td></td>
<td>FCA Delete</td>
<td>TFMS</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td><strong>CTOP Trajectory Messages</strong></td>
<td>TOS</td>
<td>FOS</td>
<td>4,800</td>
<td>15,600</td>
</tr>
<tr>
<td></td>
<td>TOS Reply</td>
<td>TFMS</td>
<td>950</td>
<td>2,850</td>
</tr>
<tr>
<td></td>
<td>TOS Re-synch Request</td>
<td>FOS</td>
<td>145</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td>TOS Re-synch Reply</td>
<td>TFMS</td>
<td>971</td>
<td>3,100</td>
</tr>
<tr>
<td><strong>CTOP TMI Messages</strong></td>
<td>CTOP TMI</td>
<td>TFMS</td>
<td>290,000</td>
<td>1,529,000</td>
</tr>
<tr>
<td></td>
<td>Trajectory Assignment</td>
<td>TFMS</td>
<td>2,880</td>
<td>5,124</td>
</tr>
<tr>
<td></td>
<td>CTOP Pop-Up</td>
<td>TFMS</td>
<td>2,880</td>
<td>5,124</td>
</tr>
<tr>
<td></td>
<td>CTOP Drop-Out</td>
<td>TFMS</td>
<td>2,880</td>
<td>5,124</td>
</tr>
<tr>
<td></td>
<td>CTOP TMI List Request</td>
<td>FOS</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>CTOP TMI List Reply</td>
<td>TFMS</td>
<td>290,000</td>
<td>1,529,000</td>
</tr>
<tr>
<td></td>
<td>CTOP TMI Re-synch Request</td>
<td>FOS</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>CTOP TMI Re-synch Reply</td>
<td>TFMS</td>
<td>58,000</td>
<td>306,000</td>
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<tr>
<td></td>
<td>Trajectory Assignment Re-synch Request</td>
<td>FOS</td>
<td>29</td>
<td></td>
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<tr>
<td></td>
<td>Trajectory Assignment Re-synch Reply</td>
<td>TFMS</td>
<td>572</td>
<td>1,020</td>
</tr>
<tr>
<td></td>
<td>CTOP TMI Delete</td>
<td>TFMS</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td><strong>CTOP Substitution Messages</strong></td>
<td>CTOP Substitution</td>
<td>FOS</td>
<td>350</td>
<td>1,350</td>
</tr>
<tr>
<td></td>
<td>CTOP Substitution Reply</td>
<td>TFMS</td>
<td>350</td>
<td>1,350</td>
</tr>
</tbody>
</table>

Notes: Messages sizes are prior to any data compression applied for network transmittal.

The message frequencies along with the size of the messages will govern the bandwidth needs for any particular CDM user.
Testing Phases and Test Environments

• Pre-OT&E (Operational Testing and Evaluation)
  – Informal external interface tests with live data
  – Ensures operational viability of CTOP interfaces and data exchange prior to formal testing

• OT&E
  – Live tests conducted formally by FAA with CSC support at the TPC
  – Includes the ATCSCC “early look” tests with field personnel
  – End to end connectivity verification accomplished

• KSAT (Key Site Acceptance Test)
  – Focuses on functionality and connectivity tests
  – Conducted under operational conditions
  – Performed with live data between the TPC, the ATCSCC and an ARTCC (site to be determined)

CDM CTOP message exchange can be available within this test phase as this is the earliest time that stable software will exist.
CTOP Test Environments

• TAP stands for (TFMS Auxiliary Platform)
  – Each TAP is a Separate Test Environment loaded with either the current operational version of software (Release 3) or have the next version to be released
  – A TAP that will be configured with the CTOP software for CDM user community pre-production testing

• Each TAP, is isolated from the operational system
  – Each is configured to receive live data feed from a message forwarding component of the operational system.
  – One way flow of data (live flight data to a TAP)
  – All non-operational data on a TAP is prevented from going onto the operational system

• Access to the test environments for CDM customers will require that a separate connection to be created to access the TAPs
  – Current Operational CDM network connections (Ops) are not permitted to access the test environments
  – A separate non-operational service delivery point or gateway (referred to as the FAA National Test Bed or FNTB) provides isolation from the operational system and access to the TFMM test environments
Establishing Network Connectivity to the Test Environments

- Configurations are in place now for the VPN connections to begin
  - Change request forms that contain the IP addresses of the new services has been distributed to everyone
- ARINC will be establishing AOCNET customer access to the test environments. The connectivity decision to use either a VPN or AOCNET is a business decision each CDM participant can make
- Avoid the rush - Act Now to get test connectivity established!!
  - Connectivity to the test environments cannot be supported over operational CDM networks
CTOP Industry Day

A Seminar on the Collaborative Trajectory Options Program

October 13, 2010