Dynamic Weather Routes Architecture Overview

Hassan Eslami (UCSC UARC)
Michelle Eshow (NASA)
2/18/14
CTAS (Center/TRACON Automation System) Software Platform Overview

- CTAS: A platform for real-time, trajectory-based automation and controller decision support tools

- Notable controller decision support tools based on CTAS
  - Traffic Management Advisor (TMA)
  - Direct-To (D2)
  - Terminal Sequencing and Spacing (TSS)
  - Dynamic Weather Routes (DWR)

- CTAS main internal functions:
  - External input data processing (Flight plans, Tracks, Weather, Wind)
  - 4-D trajectory generation
  - Decision automation algorithms
  - Advisories generation
  - Interactive decision support graphical user interface
General CTAS System in Live Data Context

Live track data from direct FAA-to-NASA feeds

CTAS

Host or ERAM Track, Flight Plan Messages

Airspace Adaptation Data

Aircraft Performance Data

Rapid Refresh Wind Forecast

Corridor Integrated Weather System Convective Forecast
Direct-To System in Live Data Context

Direct-To does not use weather data

Host or ERAM Track, Flight Plan Messages

CTAS

Airspace Adaptation Data

Aircraft Performance Data

Rapid Refresh Wind Forecast

2/18/14  Version 1
DWR System in Live Data Context

ASDI Track, Flight Plan Messages
Host or ERAM Track, Flight Plan Messages
FACET (Future ATM Concept Development Tool)
CTAS
Airspace Adaptation Data
Aircraft Performance Data
Route Traffic
Management Initiatives Data
Special Use Airspace
Rapid Refresh Wind Forecast
Convective Weather Avoidance Contours
Corridor Integrated Weather System Convective Forecast

2/18/14 Version 1
DWR Input Data Sources and Update Rates

- Host/ERAM data (Flight plan, Track, etc.): Direct NASA-FAA feeds - 12 sec
- NAS configuration Chart Change Update from FAA (adaptation): From FAA - 56 days
- Aircraft performance data: NASA - static
- Corridor Integrated Weather System (CIWS) Convective Forecasts: From FAA - 5 Min, 120 min forecast
- Convective Weather Avoidance Contours (CWAM): Data derived from CIWS by CTAS weather processing scripts - 5 min, 120 min prediction
- Wind information (Rapid Refresh – RR): From NOAA - 60 minutes update and prediction
- Special Use Airspace (SUA) data: From public web site - 15 min
- Aircraft Situation Display to Industry (ASDI) data: FAA - 1 min
- Traffic Flow Management Data to Industry (TFMDI) for route traffic management initiative information: FAA - 5 min
CTAS Software Components

- Input Source Manager (ISM)
- Planview Graphical User Interface (PGUI)
- Timeline Graphical User Interface (TGUI)
- Route Analyzer (RA)
- Trajectory Synthesizer (TS)
- Profile Sector En-route (PFSE)
- Dynamic Planner (DP)
- AutoResolver (AAC)
DWR Software Components

- Input Source Manager (ISM)
- Route Analyzer (RA)
- Trajectory Synthesizer (TS)
- Communications Manager (CM)
- Planview Graphical User Interface (PGUI)
- Profile Sector En-route (PFSE)
- AutoResolver (AAC)

2/18/14
DWR Software Components
ISM, CM, RA

• **ISM (Input Source Manager)**
  – Integrates and consolidates data from Center Host Computers (Host or ERAM)
  – Performs flight state filtering and state estimation (heading, vertical speed)

• **CM (Communications Manager)**
  – Internal data exchange hub for CTAS processes (PFSE, RA, PGUI)

• **RA (Route Analyzer)**
  – Generates all possible horizontal trajectories a flight may take, using TS (Trajectory Synthesizer)
  – Intended for arrival traffic; only one route generated for DWR case

**Note:** All processes read adaptation data at start-up
DWR Software Components
PFSE, PGUI

• PFSE (Profile Selector En-Route)
  – Multi-threaded algorithm engine
  – Uses multiple threads of **TS (Trajectory Synthesizer)** and **AAC (Advance Airspace Concept/Auto Resolver)** for trajectory and maneuver calculations
  – Generates among many data types, conflict and advisory information

• PGUI (Planview GUI)
  – Interactive decision support graphical user interface
  – Mimics the controller DSR

Note: All processes read adaptation data at start-up
DWR Software Components

TS, AAC

- **TS (Trajectory Synthesizer)**
  - Invoked by PFSE and RA
  - Uses aircraft’s position data (initial and destination), performance data, speed information, route list, and wind information to predict flight path profile (horizontal, vertical, speed, time, turns, etc.)

- **AAC (Advance Airspace Concept/Weather and Traffic Auto Resolver)**
  - Invoked by PFSE
  - Accepts as input data the trajectory, route, and conflict information
  - Proposes potential conflict free maneuvers
  - PFSE and AAC reiterate on intermediate maneuvers and conflict information towards a final conflict free maneuver
Direct-To Software Components – Foundation for DWR

Input Source Manager (ISM)

Route Analyzer (RA)

Trajectory Synthesizer (TS)

Communications Manager (CM)

Profile Sector En-route (PFSE)

Direct-To Algorithm

AutoResolver (AAC)

Direct-To List
DWR Changes to Direct-To Software

Performance improvements:
- Multiple TS thread
- Multiple thread of resolution cycle
DWR Internal Data Flow: RA

CM → RA: Track, Flight Plan
RA → TS: TS Input Data
TS → RA: Trajectory
RA → CM: Route Type To PFSE

Aircraft Model Database
Wind Data Storage
DWR Internal Data Flow: PFSE

- Direct-to Flight List
- DWR Resolutions, Trajectory, Traffic and Weather Conflicts, Time Savings
- Manual Trial Plan info: Auto Selection Capture Fix, Time Savings, Conflict, Trajectory
- Capture Waypoint List For All Aircraft
- Flight Plan Trajectory Status (Success, Failure)

- Maneuver - Capture And Auxiliary Waypoints

- Manual Trial Planning Data
- Aircraft Information
- Traffic & Weather Conflict
- Trajectory Time Steps & Waypoints
- AAC Parameter File Location
DWR Internal Data Flow: PGUI

- Sector Loading Information
- Trial Plan Request for Sector Analysis

CM

Track, Flight Plan, Weather File Name

- Data To FACET
- Data From FACET
- Data To PFSE
- Data From PFSE

PGUI

* Direct-To Flight List
* DWR Resolution, Trajectory, Traffic and WX Conflicts, Time Savings
* Manual Trial Plan info: Auto Select Capture Fix, Time Savings, Conflict, Trajectory
* Capture Waypoint List For All Aircraft
* F.P. Trajectory Status (Success, Failure)

* Trial Plan Maneuver Request
* Trajectory Data Request
* Conflict Prediction Parameters (adjusted from PGUI)
DWR/CTAS Host Data Elements: Host Flight Plan

• **Time received**

• **Aircraft Identification**
  – Host Computer Aircraft ID
  – Call sign
  – Aircraft data/type (FAA designated type)
  – Beacon code

• **Facility Information**
  – Controlling Facility

**Note:** Flight plan information is required on initiation of a flight and whenever the value of an element changes.
DWR/CTAS Host Data Elements:
Host Flight Plan – Cont’d

- **Flight Information**
  - Filed true airspeed
  - Assigned altitude
  - Planned route
  - Center Parsed Route (AK Route)
  - Coordination fix
  - Coordination time
  - Temporary Altitude

- **Status**
  - P(proposed): Flight that will take off at some future time (Proposed or planned)
  - E(Estimated): Flight that is crossing center boundaries and will be picked up in the air at the coordination fix and coordination time.
  - D(Departed): Flight that is departing an airport. Will be tracked soon.
DWR/CTAS Host Data Elements: Host Track

- Data arrival time to CTAS
- Host track time
- Aircraft Identification
  - Host Computer Aircraft ID
  - Call Sign

- Track Source Information (ARTS, STARS, HOST, ERAM)
  - Source type (used by ISM to filter)
  - Facility ID
  - Sector ID
DWR/CTAS Host Data Elements:
Host Track – Cont’d

• Flight Information
  – Altitude (feet above MSL)
  – Ground speed
  – Coasting indicator (Coast bit == ‘C’ if true)
  – Latitude
  – Longitude
DWR/CTAS Host Data Elements: Drop Track, Delete Aircraft, Time Sync

- **Drop Track:**
  - Aircraft Identification
    - Host Computer Aircraft ID
    - Call Sign
  - Controlling Facility

- **Delete Aircraft:**
  - Host Computer Aircraft ID
  - Call Sign

- **Host/Application Time Synchronization:**
  - Host time sync
  - Hours
  - Minutes
  - Seconds
CTAS Adaptation

- Each ARTCC adapted separately and updated on the 56-day FAA cycle
- Vast majority of adaptation from FAA sources, including NFDC, ACES, and ERAM data
- Definition of arrival procedures generated by hand (e.g., meter fixes, stream classes, etc.)
- About 12K lines of custom adaptation per site
  - Much can be modeled on existing sites
  - If arrivals not of interest, can be simplified
Software Characteristics

- Mixture of C, C++, Java, scripts
- Multi-threading used as necessary
- Message-passing is by TCP/IP message, defined by C data structures
- Each process maintains internal database of flights, via a binary tree
- Common code shared among processes, via libraries
CTAS Software Stats

• C/C++ stats:
  – 1M lines of code in 5K files
  – 800K lines of comments

• Java stats:
  – 165K lines of code in 800 files
  – 180K lines of comments

• Stats come from Understand product
CTAS Software Dependencies

• Linux or Mac OS X (NOT Windows)
  – Currently supporting RedHat 5.8, CentOS 6.4, OSX 10.7
  – 64-bit compilation using GNU GCC, Oracle Java compilers

• Various free libraries:
  – X11/Motif (graphics)
  – QT, QWT (graphics)
  – HDF5 (weather format)
  – XML (adaptation format)
  – Python
  – MySQL (optional)
CTAS Directory Structure

CTAS

- software
  - realtime_procs
    - comm_mgr
    - dynamic_planner
    - etc.: 1 dir per process
  - offline_procs
    - libraries
    - Various analysis tools
- adaptation
  - scripts
  - ZFW
  - ZAB
  - etc