Dynamic Weather Routes
Architecture Overview

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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
Direct-To System in Live Data Context

Direct-To does not use weather data
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**

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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)
- Dynamic Planner (DP)
- Profile Sector En-route (PFSE)
- Trajectory Synthesizer (TS)
- AutoResolver (AAC)
- Route Analyzer (RA)
- Trajectory Synthesizer (TS)
DWR Software Components

Input Source Manager (ISM)

Route Analyzer (RA)

Trajectory Synthesizer (TS)

Communications Manager (CM)

Profile Sector En-route (PFSE)

Trajectory Synthesizer (TS)

AutoResolver (AAC)

Planview Graphical User Interface (PGUI)

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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
  - Trajectory Synthesizer (TS)
  - AutoResolver (AAC)
- Direct-To List

Version 1

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DWR Changes to Direct-To Software

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

CTAS

Host or ERAM
- Track, F.P.

ASDI Feed
- Track, F.P.

Input Source Manager (ISM)
- Track, F.P.

Communication Manager (CM)

Profile Selector En-route (PFSE)

Planview GUI (PGUI)

Route Analyzer (RA)

FACET

TMI

SUA

RR

CWAM

CIWS

Airspace Adaptation Data

Aircraft Performance Data

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DWR Internal Data Flow: RA

CM → RA: Track, Flight Plan

RA → TS: TS Input Data

RA → CM: Route Type To PFSE

TS → Aircraft Model Database

TS → Wind Data Storage

Trajectory
DWR Internal Data Flow: PFSE

- Track, Flight Plan, Weather File Name
- Parsed Route for CM sim Files
- Data From RA
- Data From PGUI
- Data To PGUI
- WX. Data
- TS Input Data
- Trajectory
- From PFSE
- Maneuver Data
- AAC Parameter File Location
- Manual Trial Planning Data
- Aircraft Information
- Traffic & Weather Conflict
- Trajectory Time Steps & Waypoints
- Capture Waypoint List For All Aircraft
- Flight Plan Trajectory Status (Success, Failure)
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

- TX. Data

- 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)

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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 OSX (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