Collaborative Seamless Manager for Airspace Resources and Traffic

CSMART
Flight Planning 2019 ATM System

• The process of generating and modifying a flight plan for a flight

• The initial flight plan must be submitted to the FAA at least 45 minutes before gate push back

• Flight plans are modified by operator and/or FAA agents during flight operations

• Flight plans include flight Id, aircraft type, route, scheduled departure time, estimated arrival time, ...
2019 Flight Planning Challenges

• Operators do not collaborate with each other

• At the time of initial submission, the flight plan is not directly checked against traffic flow management constraints

• Operator flight planning options are limited by communication and FAA workforce constraints (not scalable)

• Modification of flight plans may be made by the FAA on behalf of operators

• Flight plans contain minimal schedule information with no tolerances
UTM Flight Planning

• Operators collaborate

• During generation of initial flight plan, designer receives direct feedback on how the proposed flight plan affects other traffic

• The flight planning system allows many agents to join the planning process

• Modifications to flight plans may only be made by operators or their agents

• Flight plans contain full schedule information
UTM Architecture

UTM Architecture v2019.01.29

Color Key:
- ANSP Function
- Operator Function
- Other Stakeholders

NAS Data Sources
- Common data from FAA available to UTM components based on existing access mechanisms

National Airspace System

Flight Information Management System

Supplemental Data Service Provider
- Inter-USS communication and coordination
- Terrain Weather Surveillance Performance

Constrains, Directives
- Requests, Decisions
- Operations, Deviations

Public Safety

Public

UAS Service Supplier

UAS Operator
- Operations, Constraints, Notifications, Information
- Operation request, real-time information
- Operations, Constraints, Modifications, Notifications, Information

UAS
- V2V Comm

Other Stakeholders

Additional services and components that may have shared or TBD responsibilities

Discovery Registration Data/Services Authentication/Authorization
UTM Flight Plans

Volumes I and II intersect in space and time to allow feasible transition for Operation A.

Operation A Reserves Volume I for t = 0 to 10 and for t = 18 to 24.

Volume II is directly over volume III with no intersection.

Operation A Reserves Volume II for t = 8 to 20.

Operation B Reserves Volume III for t = 0 to 4 and for t = 6 to 10.

Volumes II and IV intersect in space, but not in time.

Operation B Reserves Volume IV for t = 3 to 7.

Volumes for Operation C touch, but don’t intersect in space. Volumes intersect in time to allow transitions.

Operation C Reserves Volume VI for t = 6 to 9.

Operation C Reserves Volume V for t = 0 to 7.

Operation C Reserves Volume VII for t = 8 to 12.
UTM Applied to Other Types of Flight Operations

UTM

UAM

High Altitude

Controlled Airspace?
ATMX Project Goals for 2045 ATM System

• Seamless equitable access to the NAS resources for all users and missions
• Scalability for increased demand across users and missions
• Flexibility whenever possible and structure only when necessary
• Collaboration through integrated information exchange
• Resilience to uncertainty, degradation, and disruption by empowering localized (user-based) decision making
• Increased availability and use of user and third-party services
Applying UTM Architecture to 2045 Flight Planning

• Strengths from UTM
  • Service oriented architecture for seamless collaboration, negotiation, scalability, and flexibility
  • Flight plan that includes schedule information

• Contrasts with UTM
  • UTM is clean sheet design of traffic management system, does not have legacy systems
  • UTM does not have high density streams of critical value flights arriving on a single runway
  • Current UTM missions tend to be shorter, which minimizes the effects of uncertainty
2045 Flight Planning with UTM Architecture

• Planning horizon
  • Tactical – 0 -> 20min
  • Strategic – 20 -> ?

• ATM System Functions
  • Separation Assurance
  • Tactical Traffic Flow Management
  • Strategic Traffic Flow Management
  • Flight Planning
2045 Flight Planning with UTM Architecture

- Separation Assurance
- Tactical Traffic Flow Management
- Strategic Traffic Flow Management

- Flight Planning
  - Not time critical
  - Well suited for collaboration, negotiation, and scalability
CSMART Definition

• 2045 concept and architecture for collaborative flight planning that satisfies strategic traffic flow management constraints
  • Designs and modifies flight plans on the strategic time horizon
  • Adds schedule with tolerance information to the flight plan
  • Superseded by separation assurance and tactical traffic flow management

• Uses the UTM Architecture
  • Service oriented architecture
  • Representational state transfer system (RESTful system)
  • Composed of web services

• Consistent with FAA Trajectory Based Operations 2030 concepts
CSMART Benefits

• Increase collaboration and flexibility in flight planning for operators through digital communication across the internet considering known strategic traffic flow management constraints
  • Operators vs. Operators
  • Operators vs. FAA

• Increase system predictability
  • FAA and operator agents both work towards same schedule
  • Operators have bounds on resource use times
  • Operators are notified when bounds need to change

• Increase system efficiency through more collaboration and flexibility
Airspace Resources

• Fixes (with or without altitude constraint)
  • Merge fix
  • Arrival or departure gate
  • Waypoint

• Runways
  • Departure
  • Arrival

• Airspaces
  • Sector
  • Special Use Airspace
  • Weather polygon
  • Center
Strategic Traffic Flow Management Constraint

• Strategic traffic flow constraints are generally rate or count based
  • Rate - limit number of flights that can use a fix or runway during a time interval, e.g. an arrival runway can accept a maximum of 5 flights per 15 min bin
  • Count - limit the count of flights that can occupy an airspace at once, e.g. a sector can accommodate a maximum of 15 flights at one time

• Tactical traffic flow constraints are generally spacing requirements between flights as they pass through a resource

• Strategic constraints can be generally derived from tactical constraints— not vice versa.
Planned Trajectory

• Extend the flight plan to include a planned trajectory

• Planned trajectory is designed by operator or third party service to conform to traffic flow management constraints

• The planned trajectory is shared with all stakeholder (FAA and other Operators) agents

• Conformance with planned trajectory is tracked
Planned Trajectory

<table>
<thead>
<tr>
<th>$r_1$</th>
<th>$r_2$</th>
<th>...</th>
<th>$r_{n-1}$</th>
<th>$r_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[t_{min}, t_{max}]_1$</td>
<td>$[t_{min}, t_{max}]_2$</td>
<td>...</td>
<td>$[t_{min}, t_{max}]_{n-1}$</td>
<td>$[t_{min}, t_{max}]_n$</td>
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</tbody>
</table>

where $r =$ resource, $t_{min} =$ min time to use, $t_{max} =$ max time to use, and $n =$ the number of resources in the route
Planned Trajectory

<table>
<thead>
<tr>
<th>Route</th>
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Planned Trajectory

where \( r = \text{resource}, \ t_{\text{min}} = \text{min time to use}, \ t_{\text{max}} = \text{max time to use}, \) and \( n = \text{the number of resources in the route} \)
Creating a Resource Schedule for A

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<tr>
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<th>...</th>
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Resource Schedule

Red bars represent a time interval that a flight has previously reserved.

In general, red bars are longer higher up the timeline and shorter the lower down the timeline. This is due to uncertainty growing with time-to-use.

Do to uncertainty, the bars are allowed to overlap. In general, the green bars will be calculated from the red bars by a function to be determined by research.

Green bars represent time interval that is open for reservation by a new flight.
CSMART Architecture

• Follows UTM approach
  • Federated
  • Collaborative
  • Scalable

• Service-oriented architecture
  • Logically represents a business activity with a specified outcome
  • Self contained
  • Black box to clients
  • May consist of underlying services
CSAMRT Architecture continued

• Representational State Transfer (RESTful system)
  • Approach to satisfying Service-Oriented paradigm
  • Provides interoperability between computer systems on the Internet
  • Allows clients to textually access information on server systems by using a uniform and predefined set of stateless operations (clearly defined API)

• Each CSMART module is a Web Service
  • Communicates using HTTP protocol
    • Send message
    • Receive message
  • Each module has a URL and can reside anywhere on Internet
CSMART Modules

Four Types of Modules
1. Flight Plan Service Supplier (FPSS)
2. Flight Information Management System (FIMS)
3. Resource Schedule
4. Directory
Flight Plan Service Supplier (FPSS)

• Developed & deployed by 3rd Party/Operator

• Stores operator’s flight plans

• Function is to create and modify flight plans
Resource Schedule (RS)

• Developed and deployed by FAA

• Stores the resource’s reserved intervals

• Function is to calculate and share open intervals
Flight Information Management System (FIMS)

• Developed and deployed by FAA

• Initially does not store data

• Function is to exchange information between FAA ATM systems and CSMART
Directory

• Developed and deployed by 3rd Party/Operator community

• Stores addresses of FPSSs and RSs

• Function is to share FPSS and RS addresses
2020 Project Plan

• Conduct two simulation studies in FY20

• Simulation formed by connecting AutoResolverSim to CSMART prototype
  • AutoresolverSim models the NAS with
    • Separation assurance
    • Tactical traffic flow management
  • CSMART does flight planning
    • Predeparture – first simulation
    • Modifications to flight plans during operations – second simulation

• Analyze simulation results
  • Flight plan Stability and predictability
  • Operators ability to prioritize and negotiate
Summary

- CSMART is a concept and architecture for operators to seamlessly collaborate on flight planning while simultaneously satisfying strategic traffic flow management constraints.

- It connects operators to other operators and operators to FAA agents through the internet.

- Its benefits include flexibility, scalability, predictability, stability, collaboration, and negotiation in flight planning and strategic traffic flow management.

- The project plan is to build a CSMART prototype, connect it to autoresolverSim, execute fast-time simulation, and analyze results.