A Spatial Database for Reroute Planning

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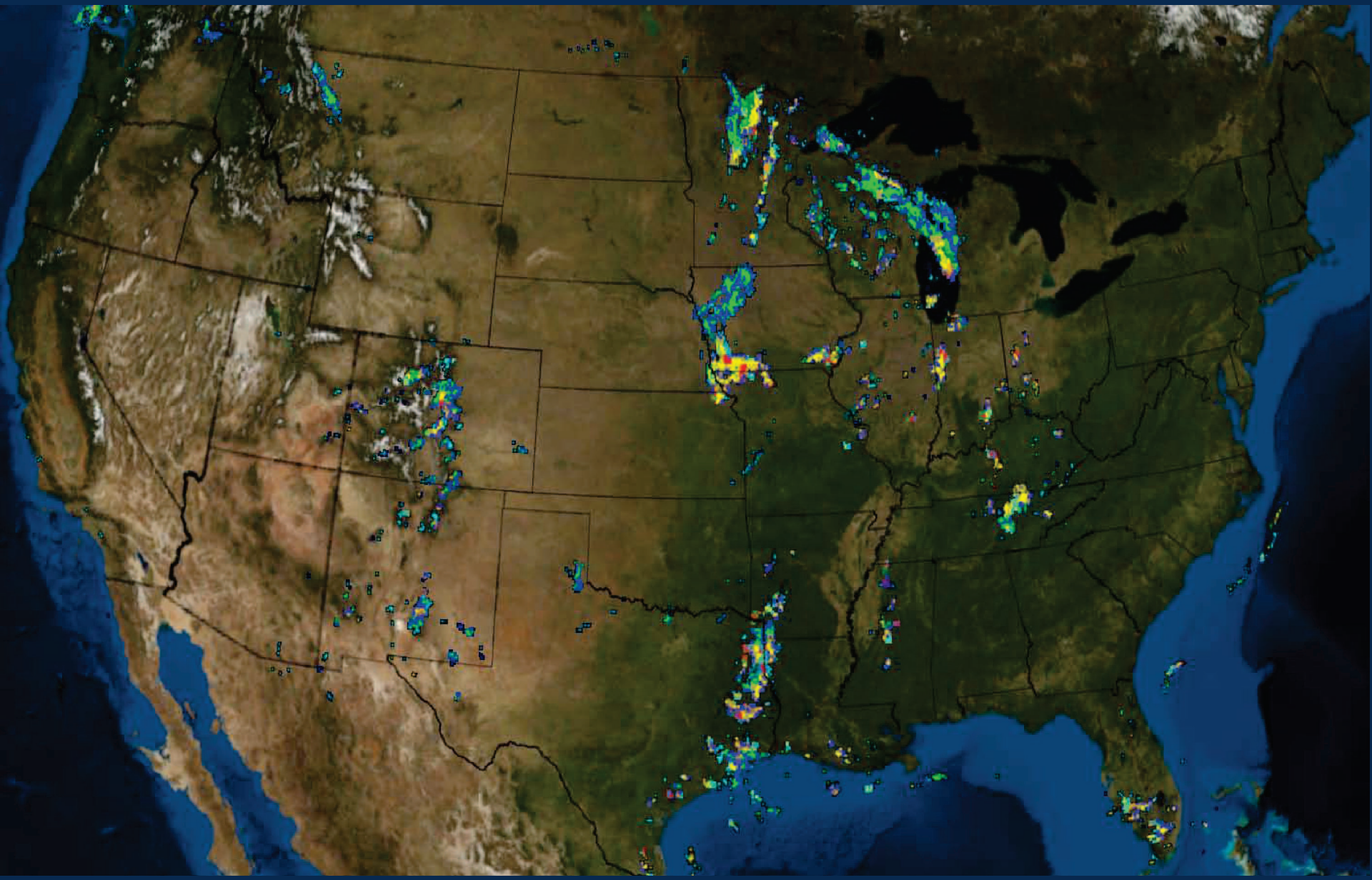
SGT, Inc.



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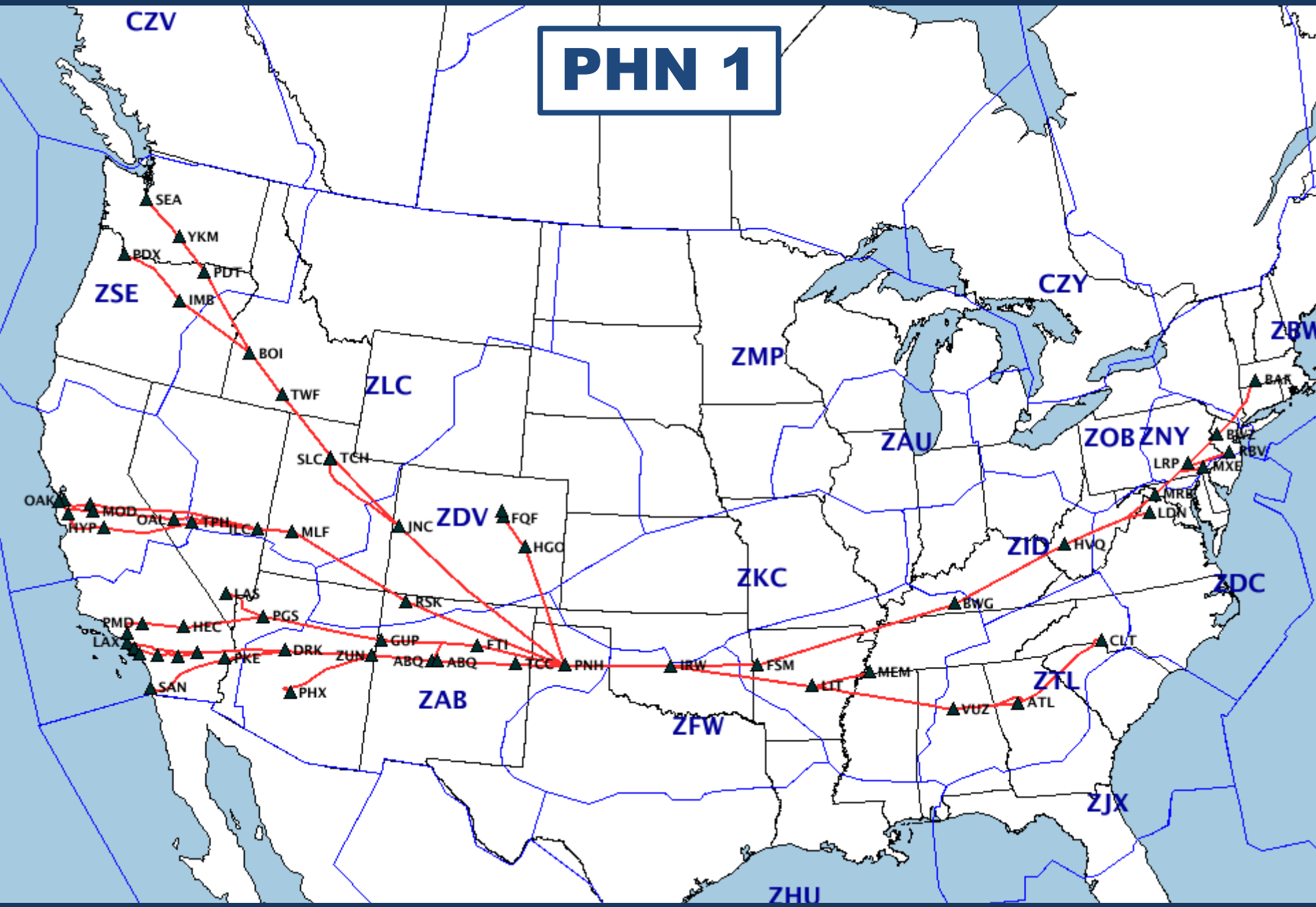
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RBV
BAF

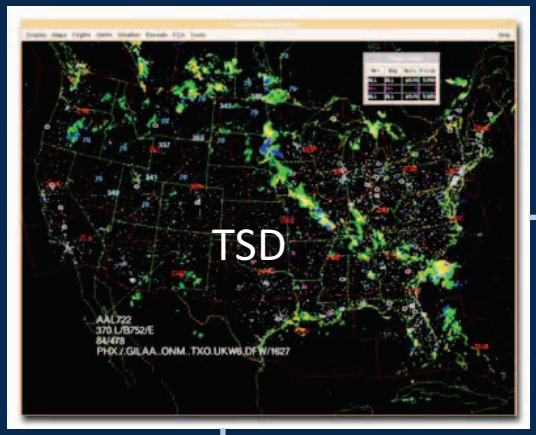
Experiment Question

Can we build a tool to leverage historical reroute decisions to inform day-of-operations decisions?

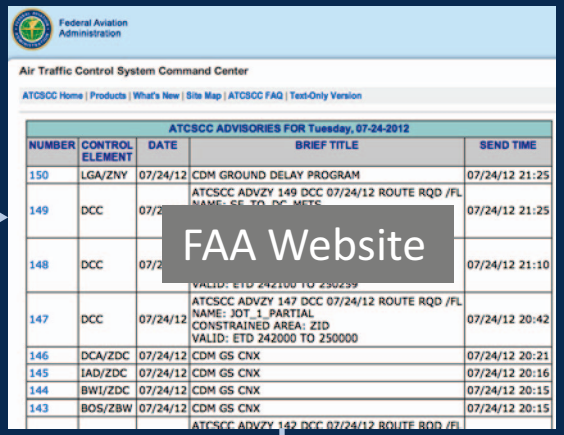
Outline

- Background
  - Reroute advisories
  - System Wide Information Management
- New Schema for Reroute Data
- Database Implementation
- Experiment and Results
- Conclusions

Reroute Data Creation, Storage, and Serving



National Traffic Management Log



Database access

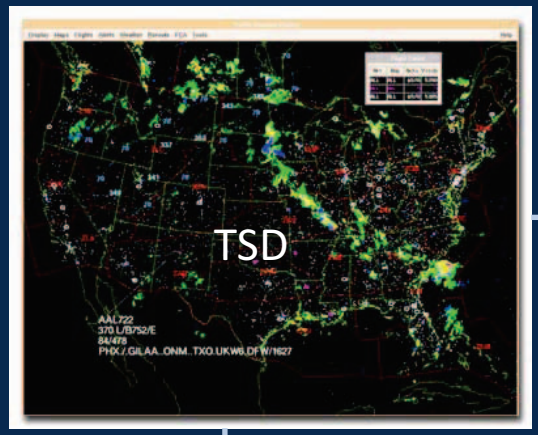
Traffic Flow Management Data to Industry

Service subscription

FAA-approved User

Public

Reroute Data Creation, Storage, and Serving



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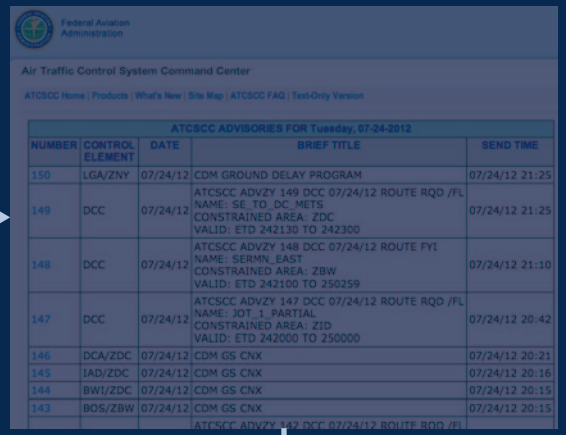

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ATCSCC ADVISORIES FOR Tuesday, 07-24-2012

NUMBER	CONTROL ELEMENT	DATE	BRIEF TITLE	SEND TIME
150	LGA/ZNY	07/24/12	CDM GROUND DELAY PROGRAM	07/24/12 21:25
149	DCC	07/24/12	ATCSCC ADVZY 149 DCC 07/24/12 ROUTE RQD /FL NAME: SE_TO_DC_METS CONSTRAINED AREA: ZDC VALID: ETD 242130 TO 242300	07/24/12 21:25
148	DCC	07/24/12	ATCSCC ADVZY 148 DCC 07/24/12 ROUTE FYI NAME: SERMN_EAST CONSTRAINED AREA: ZBW VALID: ETD 242100 TO 250259	07/24/12 21:10
147	DCC	07/24/12	ATCSCC ADVZY 147 DCC 07/24/12 ROUTE RQD /FL NAME: JOT_1_PARTIAL CONSTRAINED AREA: ZID VALID: ETD 242000 TO 250000	07/24/12 20:42
146	DCA/ZDC	07/24/12	CDM GS CNX	07/24/12 20:21
145	IAD/ZDC	07/24/12	CDM GS CNX	07/24/12 20:16
144	BWI/ZDC	07/24/12	CDM GS CNX	07/24/12 20:15
143	BOS/ZBW	07/24/12	CDM GS CNX	07/24/12 20:15

Traffic Flow Management Data to Industry

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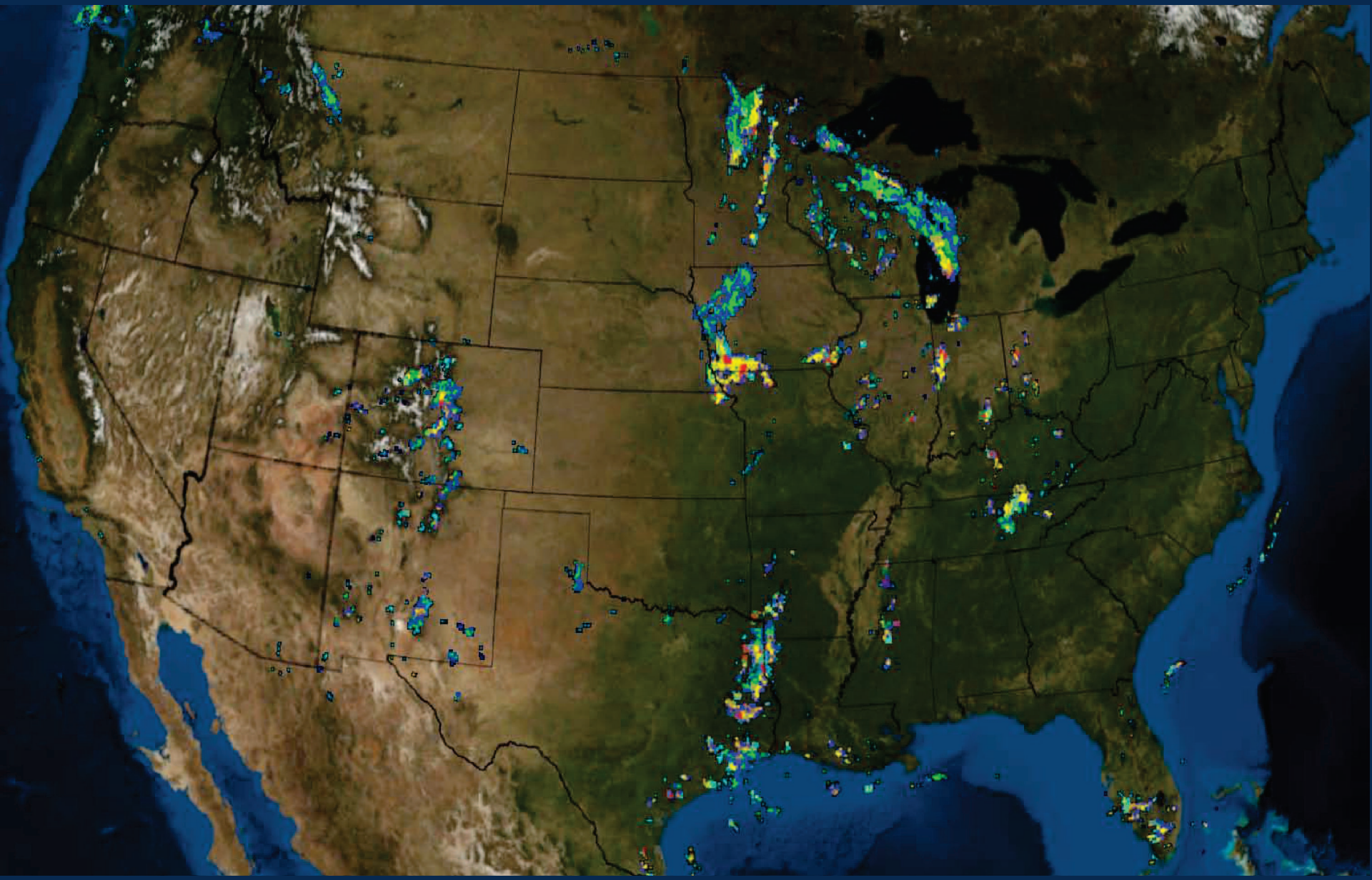

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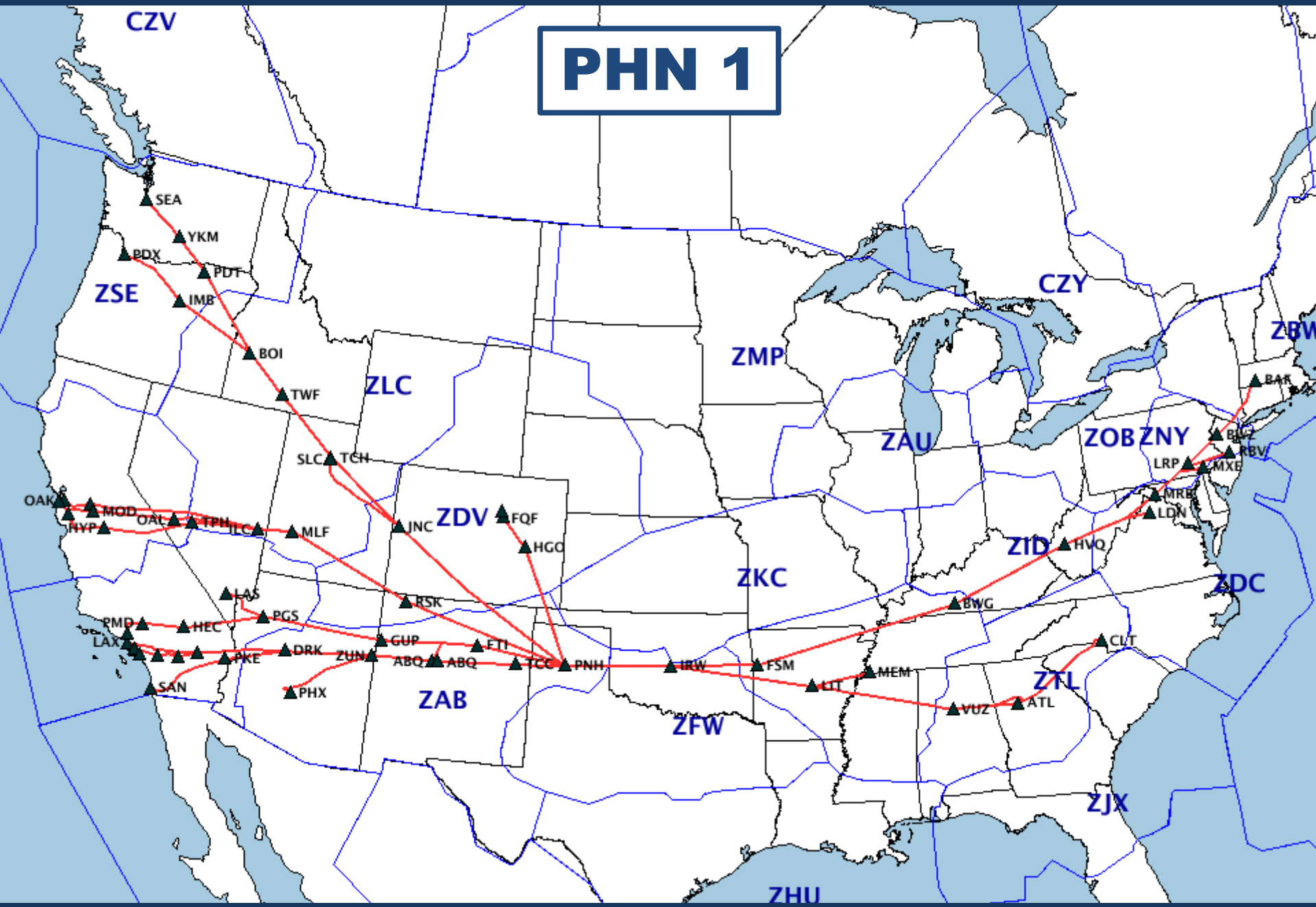
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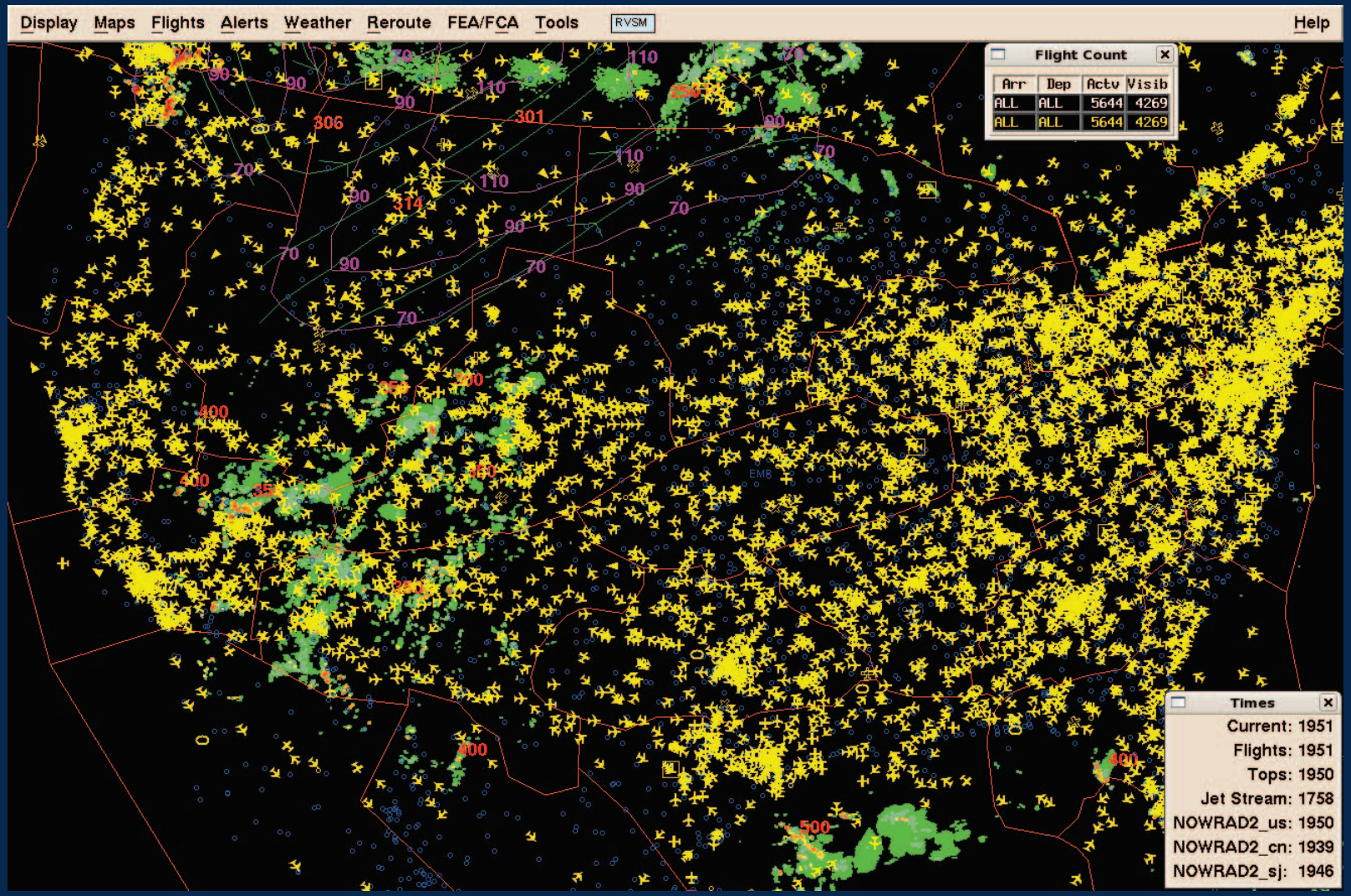
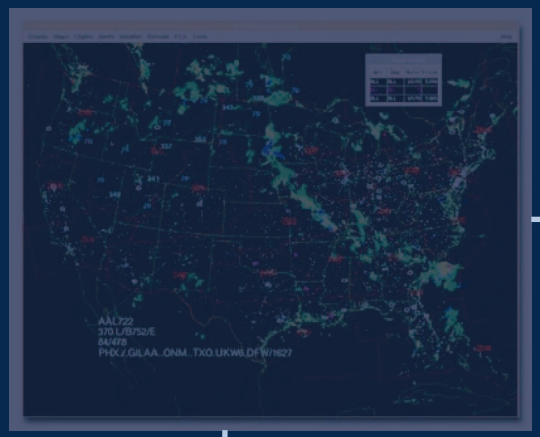
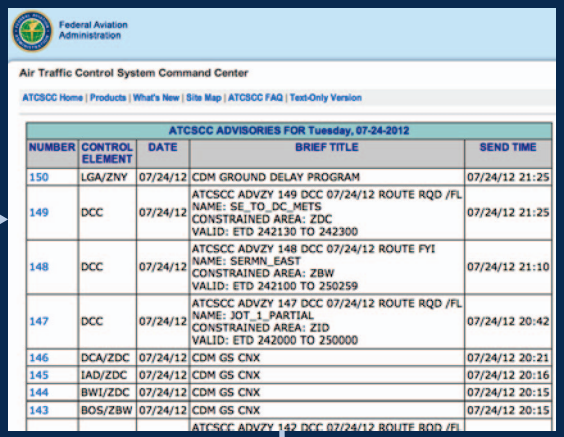
Traffic Situation Display



Reroute Data Creation, Storage, and Serving



National Traffic Management Log



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143	BOS/ZBW	07/24/12	CDM GS CNX	07/24/12 20:15
			ATCSCC ADVZY 142 DCC 07/24/12 ROUTE RQD /FL	

Traffic Flow Management Data to Industry

FAA-approved User

Public

National Traffic Management Log

- Database for traffic flow management used mostly for day-of-operations
- Stores all traffic management decisions and provides communication between Centers
- Some drawbacks
  - Not ideal for historical analysis
  - Not spatially-enabled, it is a ‘classic’ database
  - No service for users to easily collect data
  - Reroutes stored only as poorly-structured text blobs

FAA Advisories

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			ATCSCC ADVZY 142 DCC 07/24/12 ROUTE RQD /FL	

Reroute Advisory Example

ATCSCC Advisory

ATCSCC ADVZY 035 DCC 06/16/2012 ROUTE RQD /FL

RAW TEXT:

```
ATCSCC ADVZY 035 DCC 06/16/12 ROUTE RQD /FL
NAME: PNH_1_PARTIAL
CONSTRAINED AREA: ZKC
REASON: W
INCLUDE T

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VALID: ETD
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ROUTES:

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----
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TMI ID: RRDCC035
161746-170000
12/06/16 17:46  DCCOPS./nfs/lxstn28
```

```
IRW PNH
>MXE MXE278 PENSY J110 FLIRT J6
BWG ARG FSM IRW PNH

ROUTE - DESTINATION SEGMENTS
----------
PNH J58 FTI FRIHO4<
PNH J6 ZUN EAGUL5<
PNH HGO QUAIL6<
PNH J58 FTI J8 GUP J72 PGS
TYSSN3<
PNH J6 DRK J231 TNP SEAVU2<
PNH J6 DRK J231 TNP PSP KAYOH4<
PNH J78 PKE LYNDI3<
PNH J6 DRK J231 TNP PSP KAYOH4<
PNH J58 FTI J8 GUP J72 PGS HEC
LYNXX8<
PNH RSK J58 MLF ILC TATOO DUGLE
MADN5<
PNH RSK J58 MLF ILC RUMPS OAL
 MOD3<
PNH RSK J58 MLF ILC TPH CANDA
HYP5<
```

```
FROM:
ORIG                                ROUTE - ORIGIN SEGMENTS
----                                ----------
IAD DCA BWI ADW                     >LDN J134 COLNS J6 BWG ARG FSM
                                    IRW PNH
PHL                                 >MXE MXE278 PENSY J110 FLIRT J6
                                    BWG ARG FSM IRW PNH
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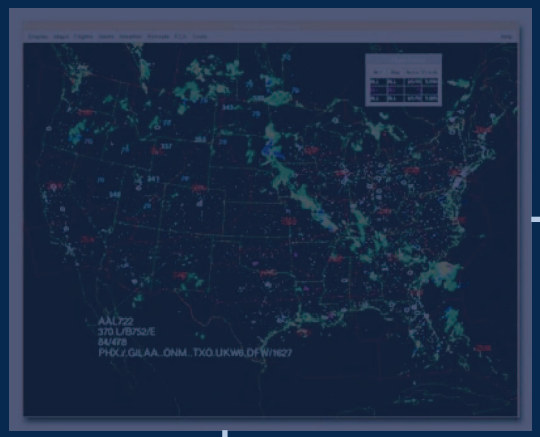
Reroute Data Creation, Storage, and Serving



National Traffic Management Log

Traffic Flow Management Data to Industry

Service subscription

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Traffic Flow Management Data to Industry

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        <SEGMENT_VALID>Y</SEGMENT_VALID>
        <ORIGIN>IAD DCA BWI ADW</ORIGIN>
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        <FULL_ROUTE>ORIG</FULL_ROUTE>
        <WAYPOINT>3885,7821,LDN,N</WAYPOINT>
        <WAYPOINT>3884,7920,COLNS,F</WAYPOINT>
        ⋮
        <WAYPOI
        <WAYPOI
        <WAYPOI
        <ROUTE_
        <SEG_SO
        <SEG_ID>
        <CTR_FLTR>
          <AIR_CAT>J </AIR_CAT>
          <USER_CAT>G T F C </USER_CAT>
        </CTR_FLTR>
</CTR_SEG>
```
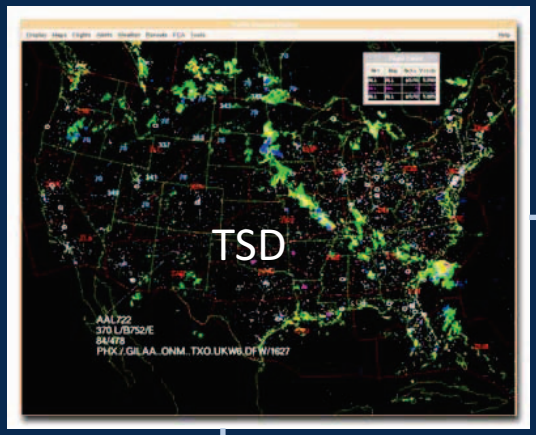
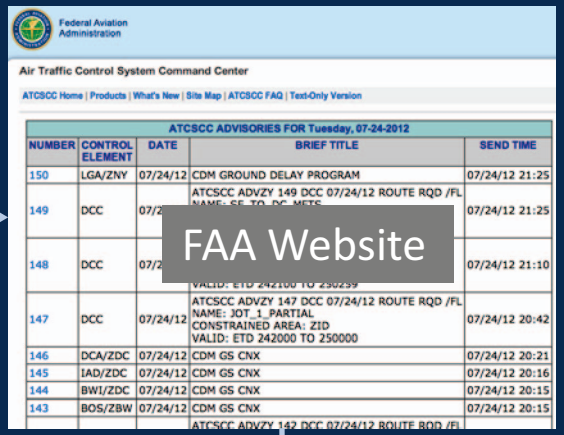

```
FROM:
ORIG
----
IAD DCA BWI ADW

PHL
```

```
ROUTE - ORIGIN SEGMENTS
-----------------------
>LDN J134 COLNS J6 BWG ARG FSM
IRW PNH
>MXE MXE278 PENSY J110 FLIPE J6
BWG ARG FSM IRW PNH
```

Reroute Data Creation, Storage, and Serving



National Traffic Management Log



Database access

Traffic Flow Management Data to Industry

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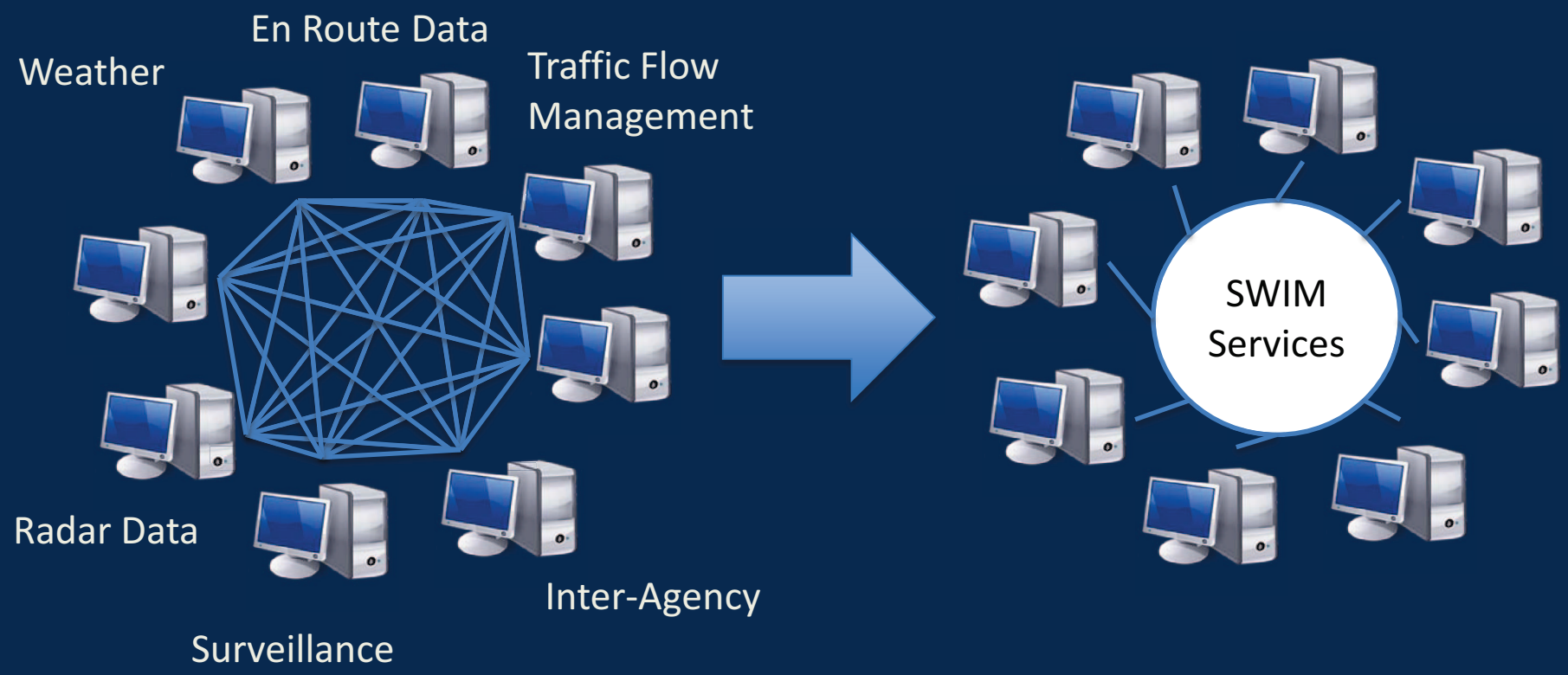
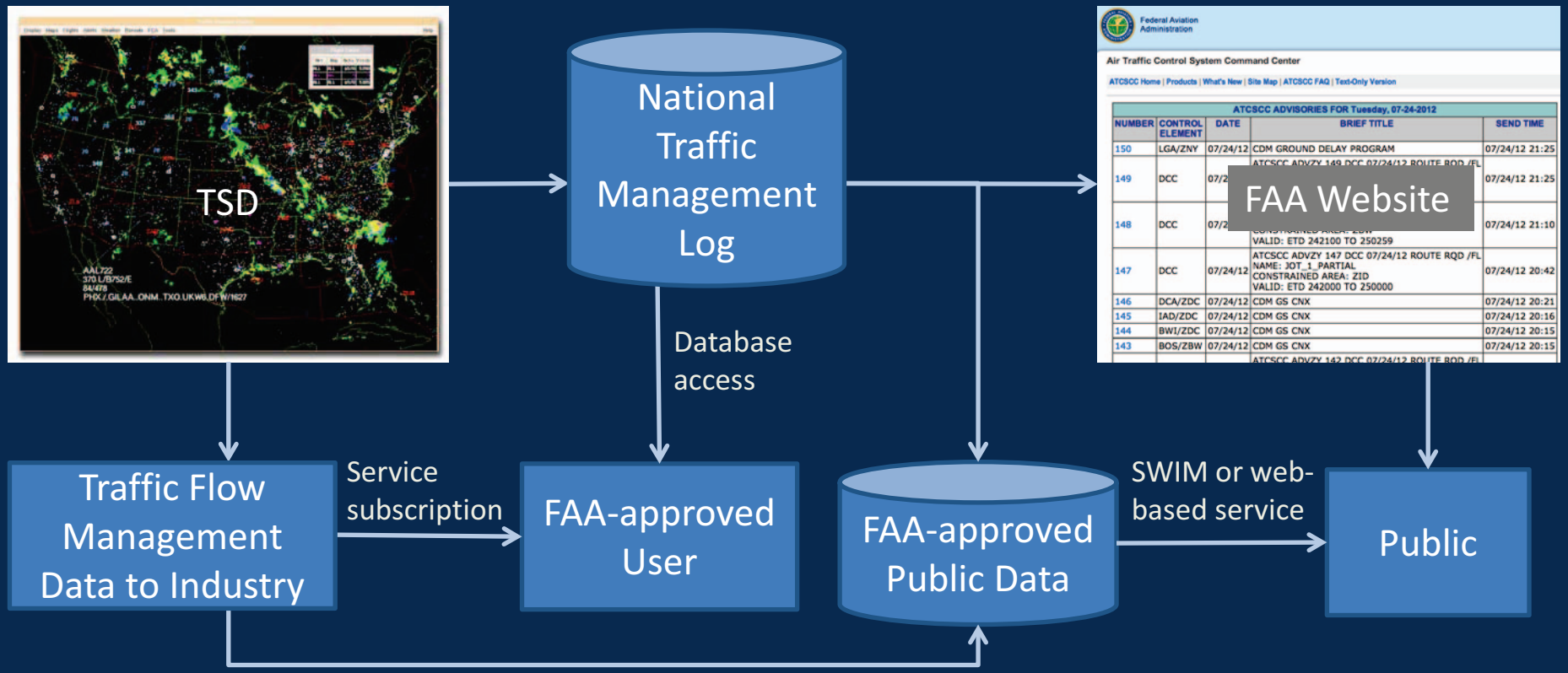
System Wide Information Management

Transition from custom, point-to-point data connections to a service-oriented architecture



Proposed Method for Serving Reroute Data

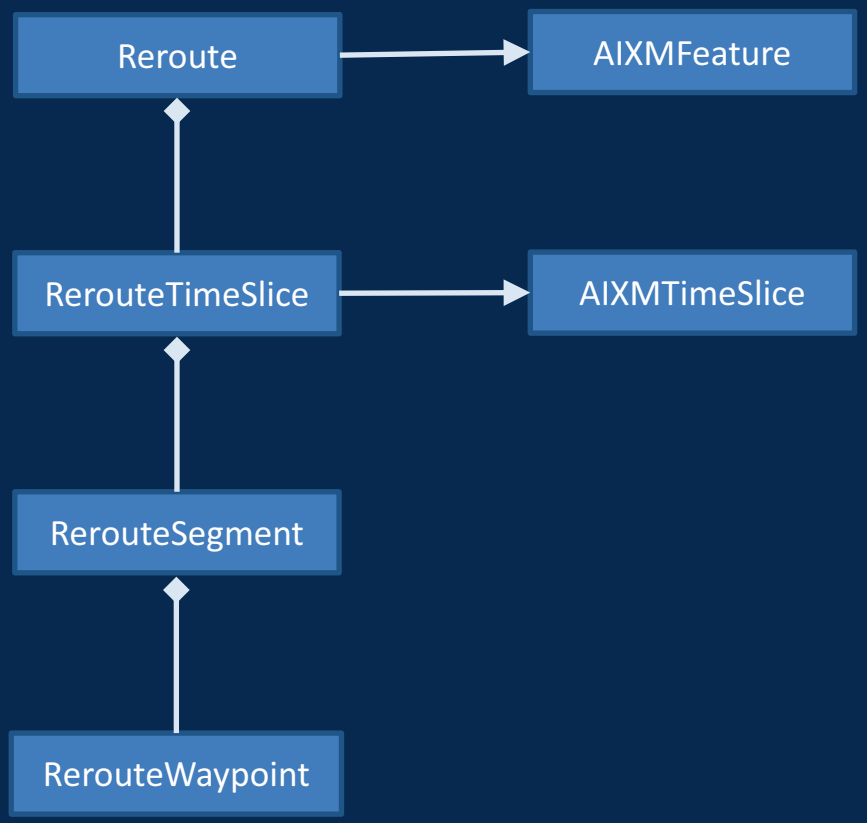


Implementing a SWIM Service (short version)

- Published data schema
- Compliant server configuration
- FAA blessing

Reroute Data Schema

The Aeronautical Information Exchange Model (AIXM) is used to build our reroute schema



Database

- Using the reroute waypoints as geographic data, we built a spatially-enabled reroute database
- The database system has a spatial extension allowing for spatial data and various spatial functions
- Populated with Traffic Flow Management Data to Industry data

Reroute Data in Database

Data Element	Count
Days	366
Reroutes	2,982
Reroute Time Slices	5,482
Reroute Segments	87,309
Distinct Reroute Segments	82,534

Observations

- Roughly two time slices per reroute
- Most reroute segments are unique
- About 3000 reroutes per year are implemented

Experiment Question

Can we build a tool to leverage historical decisions to inform day-of-operations decisions?

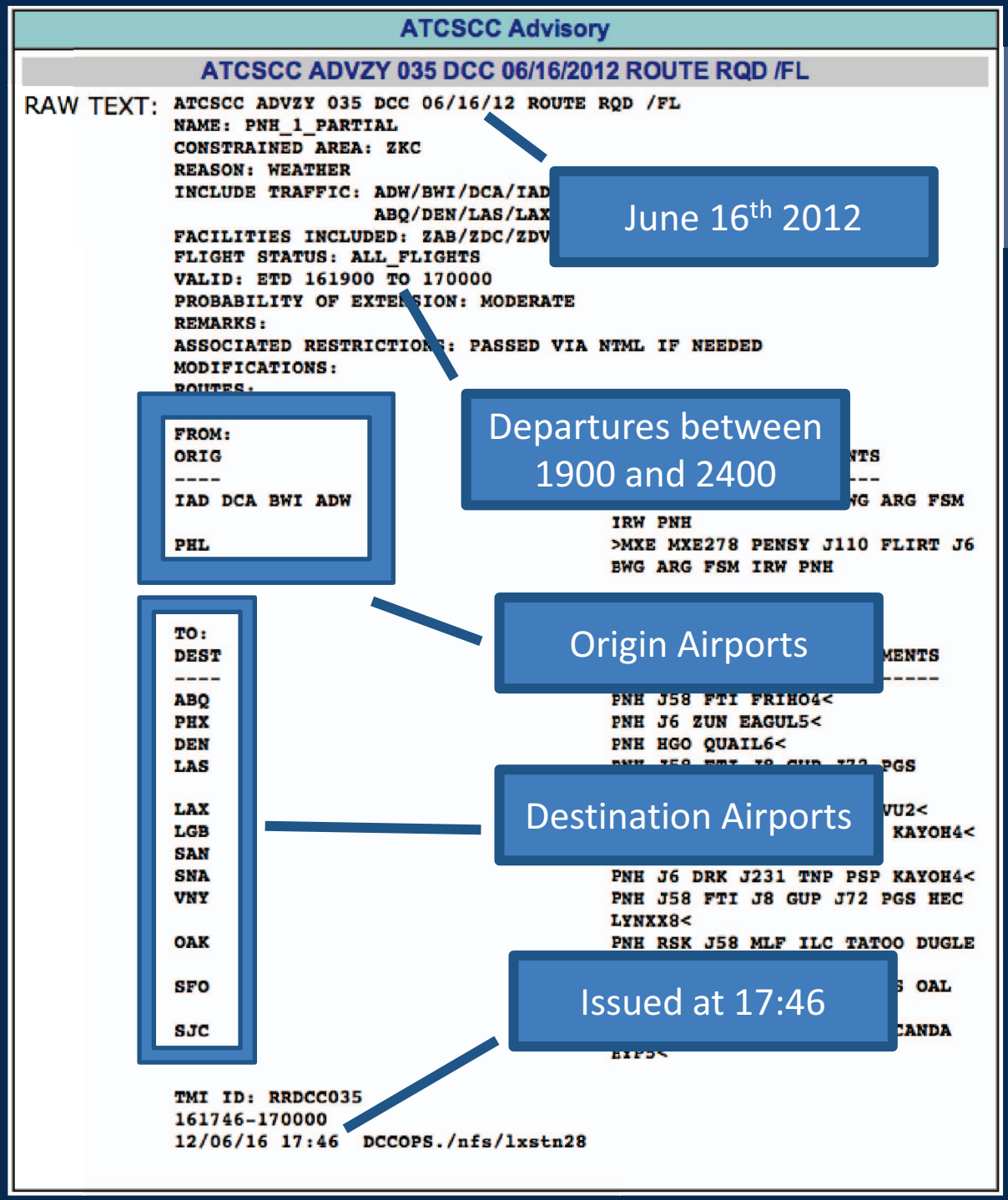
- Not formally done today
- Difficult for traffic managers to leverage experience of other managers in the moment
- Include new routes from segments of separate routes
- Ideally this would be an unobtrusive process

Reasonable Alternate Questions

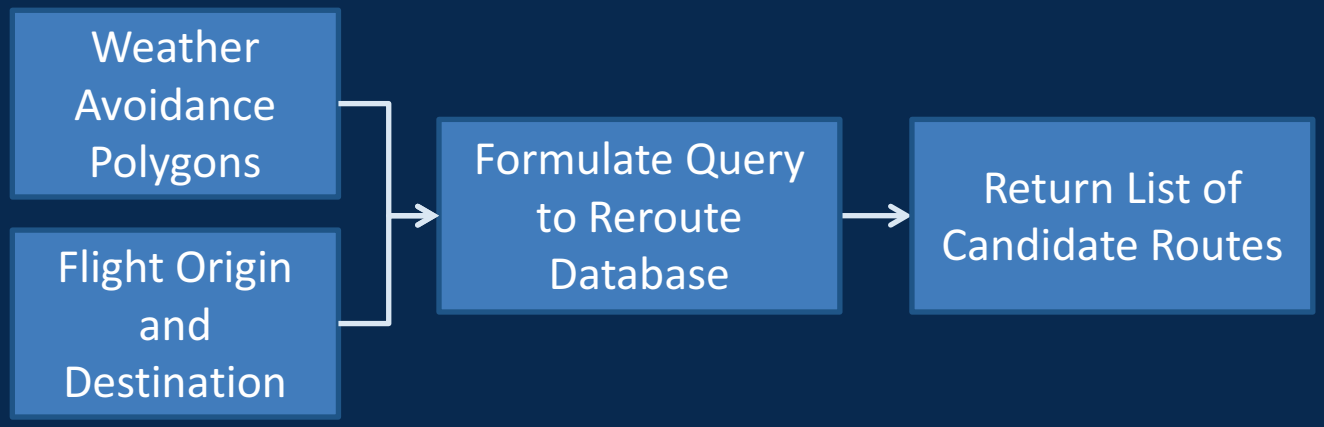
- Why not use a shortest path algorithm?
- Why bother with trouble of a spatial database?

Input Data

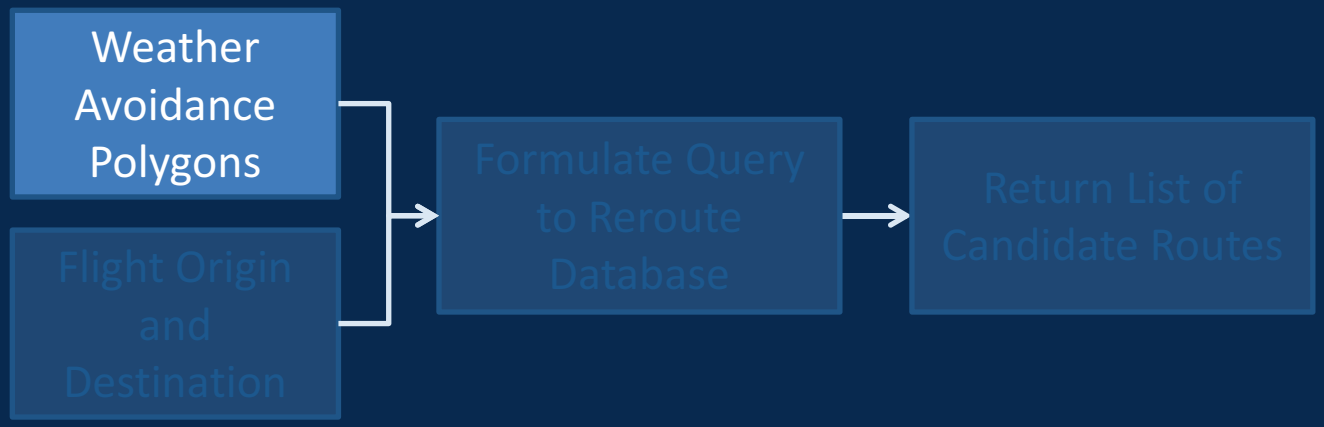
- Weather and traffic management data from June 16th, 2012
- Traffic data from June 2nd, 2012
- What if we were managing traffic at 17:45 on June



Experiment


Weather Avoidance Polygons
Flight Origin and Destination
Formulate Query to Reroute Database
Return List of Candidate Routes

Experiment


Weather Avoidance Polygons
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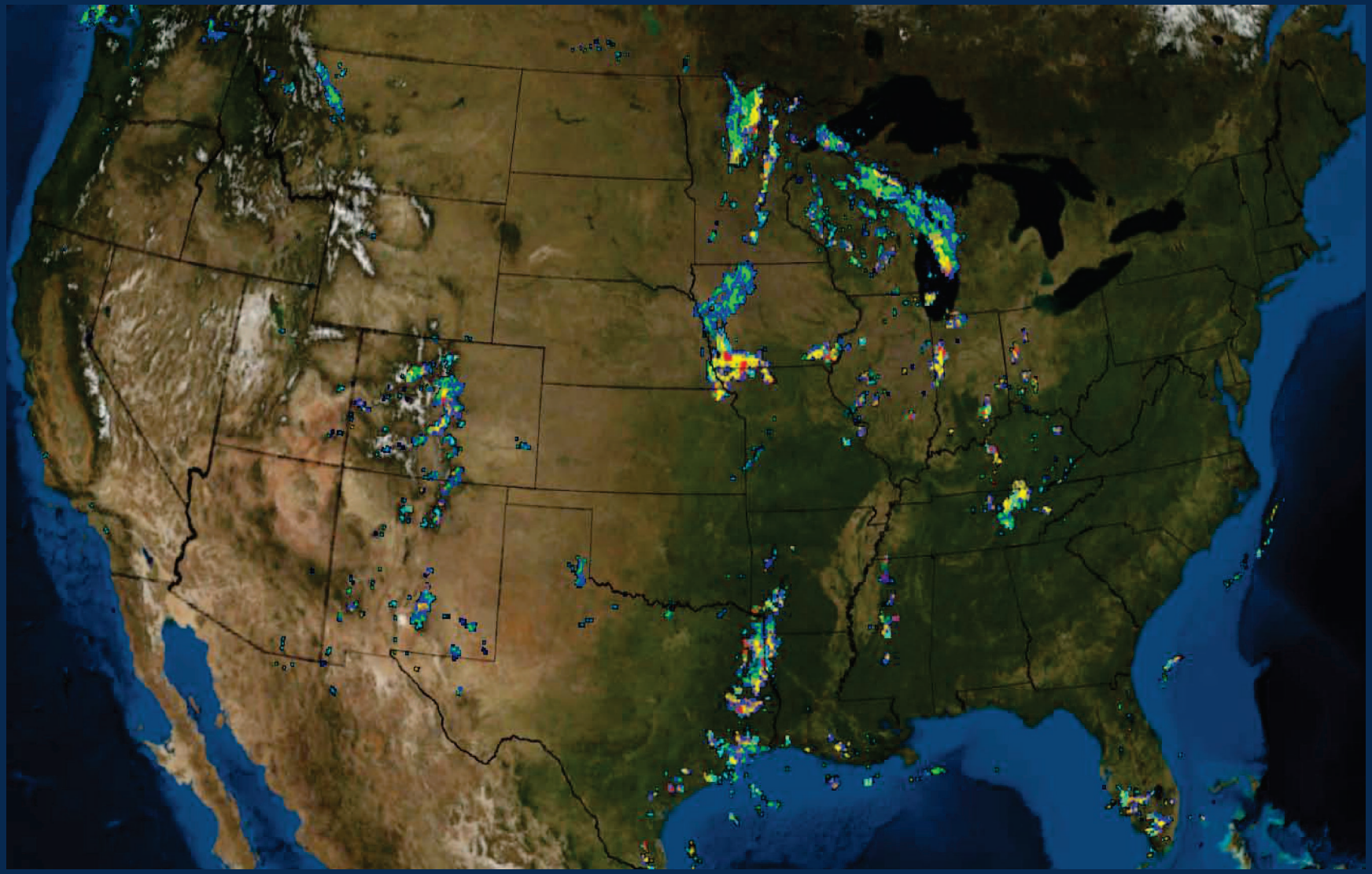
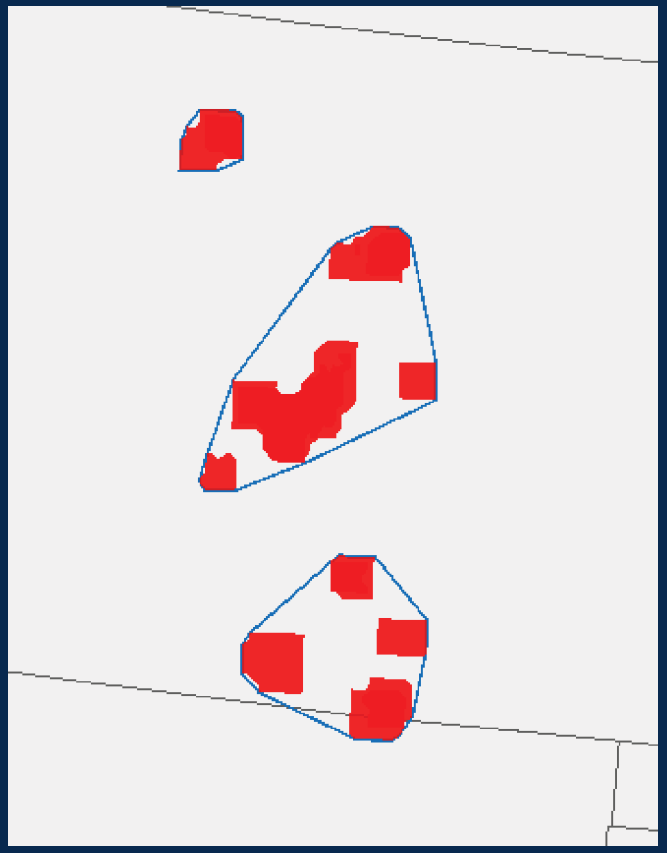
Weather Data

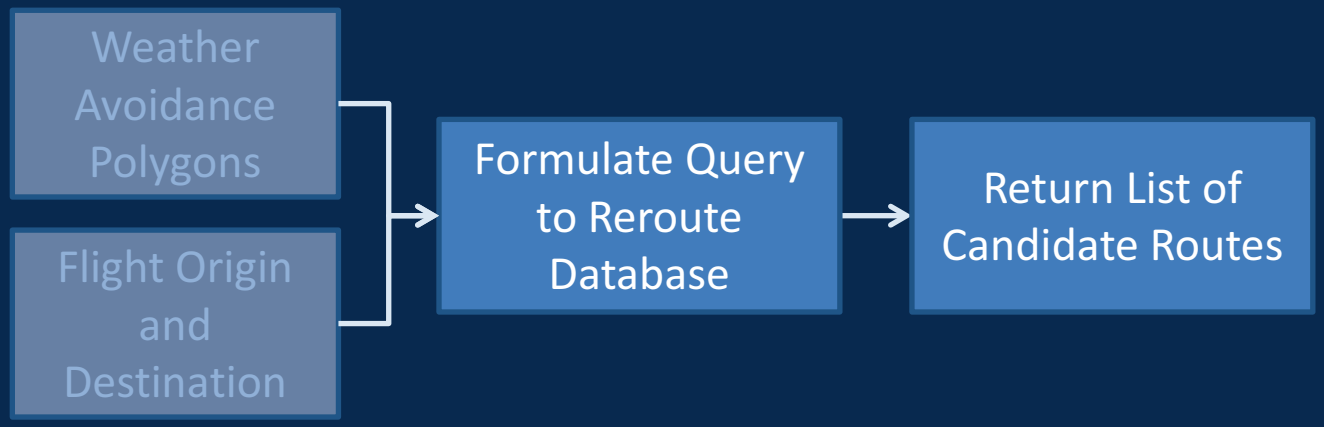


Weather Avoidance Polygons

Weather Avoidance Polygon Detail



Experiment


Weather Avoidance Polygons
Flight Origin and Destination
Formulate Query to Reroute Database
Return List of Candidate Routes

Input Parameters

```
FROM:
ORIG                                    ROUTE - ORIGIN SEGMENTS
----                                    -----------------------
IAD DCA BWI ADW                         >LDN J134 COLNS J6 BWG ARG FSM
                                        IRW PNH
PHL                                     >MXE MXE278 PENSY J110 FLIRT J6
                                        BWG ARG FSM IRW PNH
```

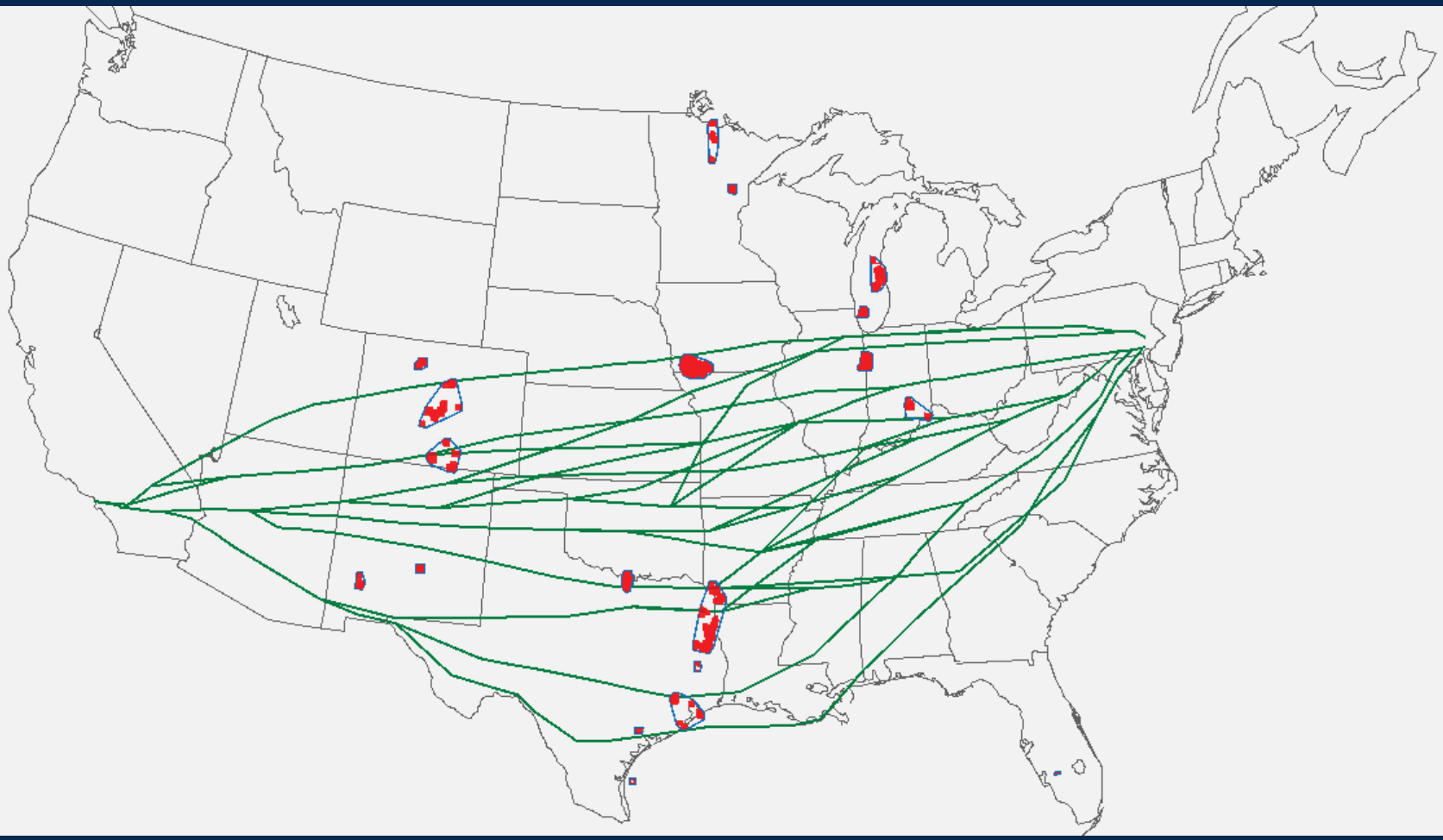
```
TO:
DEST                                    ROUTE - DESTINATION SEGMENTS
----                                    ----------------------------
ABQ                                     PNH J58 FTI FRIHO4<
PHX                                     PNH J6 ZUN EAGUL5<
DEN                                     PNH HGO QUAIL6<
LAS                                     PNH J58 FTI J8 GUP J72 PGS
                                        TYSSN3<
LAX                                     PNH J6 DRK J231 TNP SEAVU2<
                                        PNH J6 DRK J231 TNP PSP KAYOH4<
```

Query Example

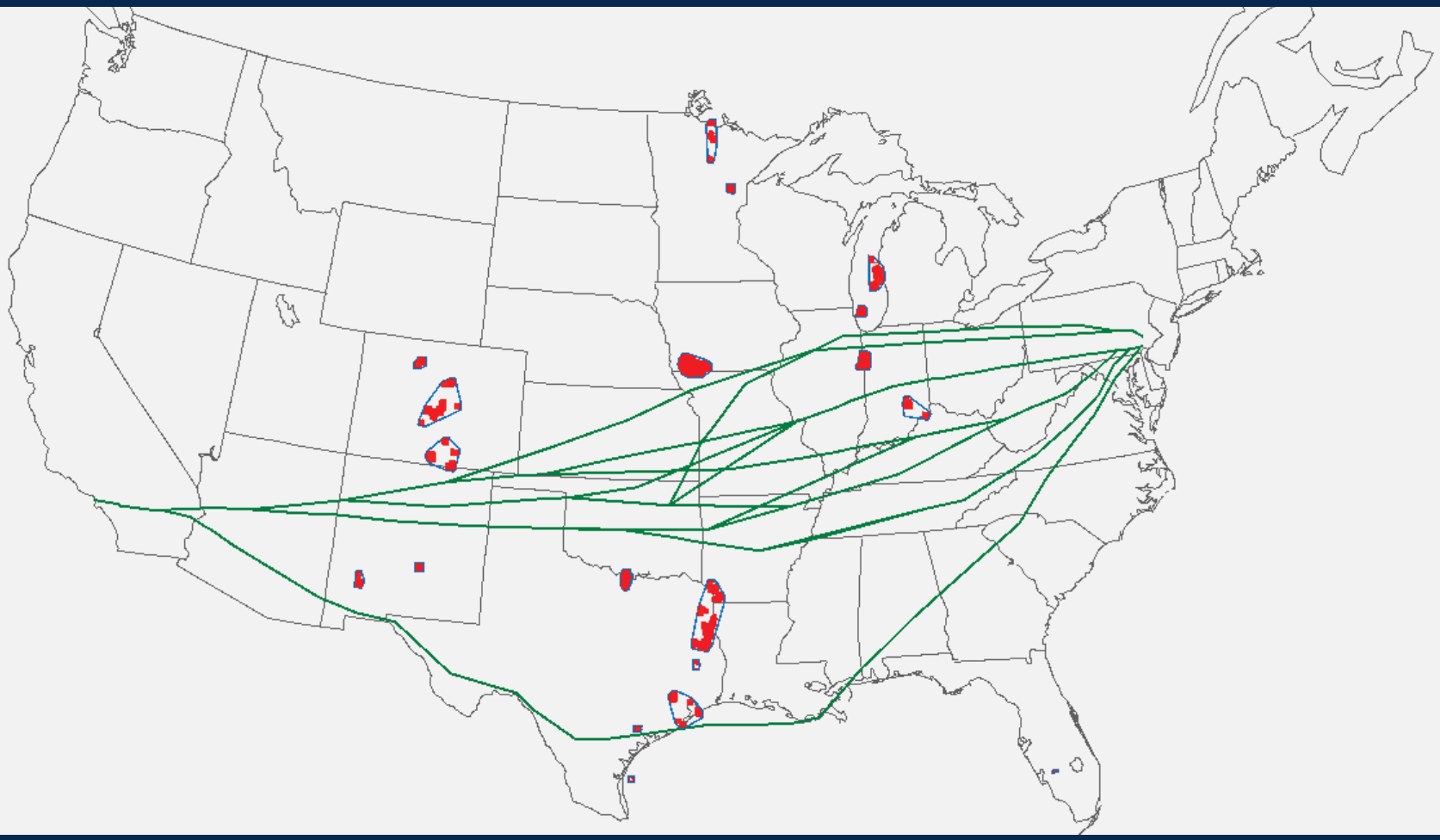
We exercise the spatial features of the database by asking only for those segments that are disjoint from the weather avoidance polygons

ST_Disjoint('POLYGON ((-83.471366 22.74464035, -83.505470 22.78559112, -83.5826492 22.79590988, -83.621238 22.80104827, -83.6598358 22.80617141, -83.6984329 22.81128311, -83.7370300 22.81638145, -83.7458419 22.7447986, -83.7502365 22.7090053, -83.759010 22.63741302, -83.7677536 22.56581115, -83.575172 22.54027366, -83.4937057 22.56574827, -83.4713668 22.74464035, -83.4713668 22.74464035))', *ST_AsText*(R1.geog)) AND
ST_Disjoint('POLYGON ((-83.471366 22.74464035, -83.505470 22.78559112, -83.5826492 22.79590988, -83.621238 22.80104827, -83.6598358 22.80617141, -83.6984329 22.81128311, -83.7370300 22.81638145, -83.7458419 22.7447986, -83.7502365 22.7090053, -83.759010 22.63741302, -83.7677536 22.56581115, -83.575172 22.54027366, -83.4937057 22.56574827, -83.4713668 22.74464035, -83.4713668 22.74464035))', *ST_AsText*(R2.geog)) AND …

PHL to LAX, Ignoring Weather



PHL to LAX, Avoiding Weather



Results

- Apply shortest reroute to each destination from PHL
- Count flights that would have been affected
- Calculate flight savings in nmi

Destination	Savings (nmi)	Flights Affected	Total Savings (nmi)
LAX	83	2	166
PHX	50	3	150
DEN	237	2	474
LAS	79	2	158
SAN	54	1	54
Total			**1002**

Research Achievements

- Designed a data schema for describing reroute advisories that is compliant with widely-accepted standards
- Implemented, populated and exercised a spatially-enabled database with historical reroute data based on the new schema
- Showed that access to historical reroute data can positively inform day-of-operations decisions

Future Work

- Implement other traffic management initiatives to our schema
  - Ground Delay Programs
  - Ground Stops
  - Airspace Flow Programs
  - Miles-in-Trial Restrictions
- Add service layer compatible with SWIM
- Create various client applications
- Open service to beta testers

Questions?

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Backup slides

Challenge

GIVEN:

- 82,000 routes between various airports and waypoints
- Set of origin-destination pairs

FIND:

- List of potential routes between origin-destination pairs
- Ordered by distance

NOT SO HARD

Challenge

GIVEN:

- 82,000 routes between various airports and waypoints
- Set of origin-destination pairs
- Set of polygons to be avoided

FIND:

- List of potential routes between origin-destination pairs
- Ordered by distance
- Avoiding all provided polygons

MUCH HARDER

Traffic Flow Management Data to Industry


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</CTR_HEAD>
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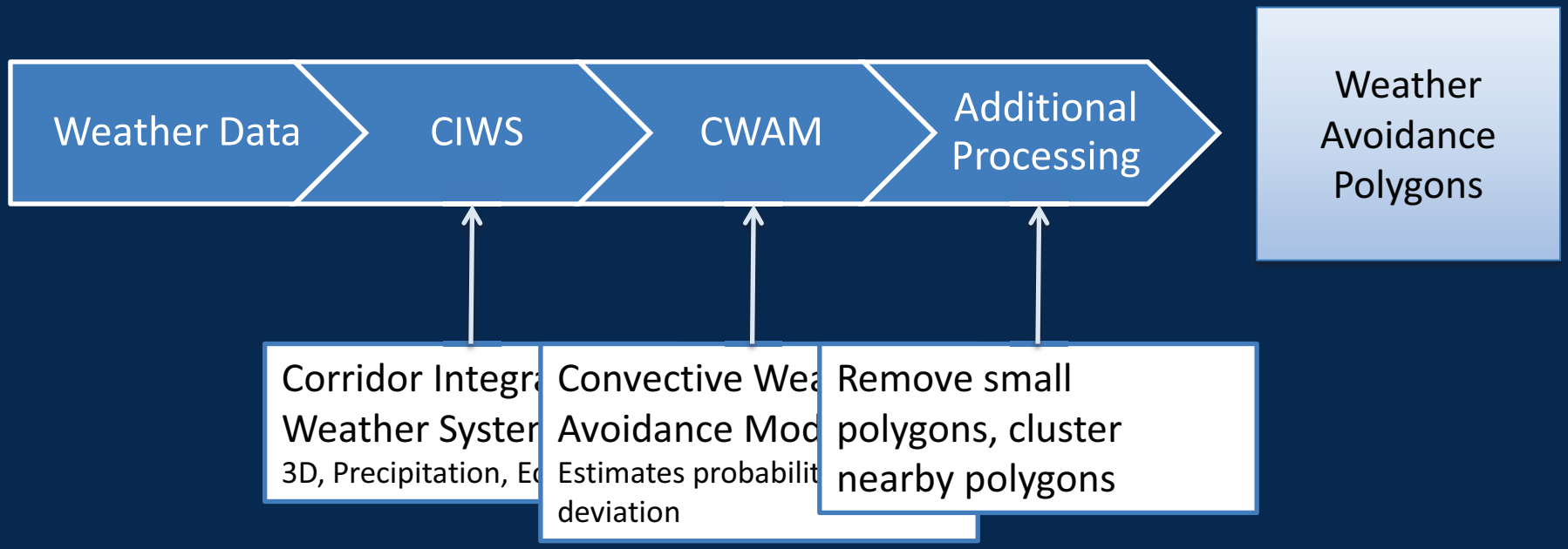
Creating Weather Avoidance Polygons



Query Example

```
SELECT DISTINCT
 ST_AsText(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog))))),
 ST_Length(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog)))))), true)
 AS seg_distance,
 R1."routeStr", R2."routeStr",
 left(R1."routeStr", char_length(R1."routeStr") - 3) || R2."routeStr”
 as "complete route"
FROM
 "RerouteSegment" AS R1,"RerouteSegment" AS R2
WHERE
 R1.origin = 'PHL' AND R2.destination = 'LAX' AND
 R1."fullRoute" = 'ORIG' AND R2."fullRoute" = 'DEST' AND
 right(R1."routeStr", 3) = left(R2."routeStr", 3) AND
```

Query Example

```
SELECT DISTINCT
 ST_AsText(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog))))),
 ST_Length(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog)))))), true)
 AS seg_distance,
 R1."routeStr", R2."routeStr",
 left(R1."routeStr", char_length(R1."routeStr") - 3) || R2."routeStr"
 as "complete route"
FROM
 "RerouteSegment" AS R1,"RerouteSegment" AS R2
WHERE
 R1.origin = 'PHL' AND R2.destination = 'LAX' AND
 R1."fullRoute" = 'ORIG' AND R2."fullRoute" = 'DEST' AND
 right(R1."routeStr", 3) = left(R2."routeStr", 3) AND
```

Functions provided by PostGIS database

Query Example

```
SELECT DISTINCT
 ST_AsText(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog))))),
 ST_Length(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog)))))), true)
 AS seg_distance,
 R1."routeStr", R2."routeStr",
 left(R1."routeStr", char_length(R1."routeStr") - 3) || R2."routeStr"
 as "complete route"
FROM
 "RerouteSegment" AS R1,"RerouteSegment" AS R2
WHERE
 R1.origin = 'PHL' AND R2.destination = 'LAX' AND
 R1."fullRoute" = 'ORIG' AND R2."fullRoute" = 'DEST' AND
 right(R1."routeStr", 3) = left(R2."routeStr", 3) AND
```

Columns in database stored as geographic data

Query Example

```
SELECT DISTINCT
 ST_AsText(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog))))),
 ST_Length(ST_LineMerge(ST_Collect(
   ST_GeomFromText(ST_AsText(R1.geog)),
   ST_GeomFromText(ST_AsText(R2.geog)))))), true)
 AS seg_distance,
 R1."routeStr", R2."routeStr",
 left(R1."routeStr", char_length(R1."routeStr") - 3) || R2."routeStr"
 as "complete route"
FROM
 "RerouteSegment" AS R1,"RerouteSegment" AS R2
WHERE
 R1.origin = 'PHL' AND R2.destination = 'LAX' AND
 R1."fullRoute" = 'ORIG' AND R2."fullRoute" = 'DEST' AND
 right(R1."routeStr", 3) = left(R2."routeStr", 3) AND
```

Ensure we are connecting appropriate segments