Status of Scenario Generation Task

FAA William J. Hughes Technical Center

ACT-250 CP Assessment Team

Mike Paglione

Bob Oaks

Hollis Ryan

Scott Summerill

September 29, 1999

Briefing Outline

- Overall Task Description
- Schedule
- Methodology
- Team Assignments
- Individual Task Descriptions & Status
- Risk Areas

Overall Task Description*

- **"Develop the necessary tools**, infrastructure and documentation required to create URET CCLD accuracy scenarios that represent the characteristics of the Design Workload."
- **"Participate in the data collection** of field data required for development of the URET CCLD accuracy scenarios."
- **"Develop a sample version and two actual URET CCLD traffic scenarios** for the accuracy testing for FAA's acceptance testing of URET CCLD."
- **"Perform a trajectory accuracy analysis** using the developed accuracy scenarios on URET 'daily use' system so that AUA-200 can refresh the URET CCLD system specification accuracy metrics."

*Source: FY99 and FY00 PDs

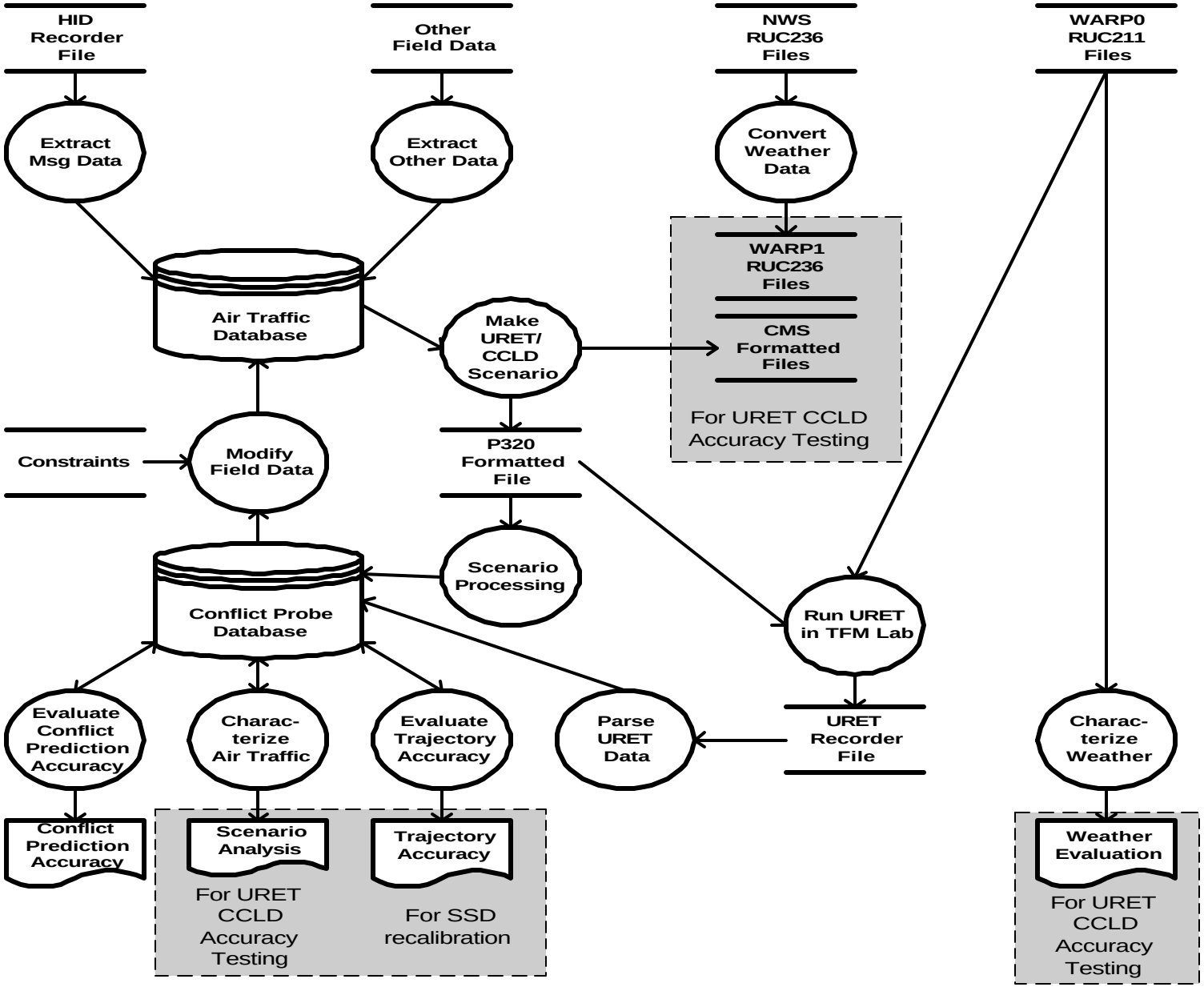
Main Task Item Schedule

- FY99 PD
  - Trajectory Accuracy Report
    - » completed 5/99 ✓
  - Develop Necessary Tools
    - » ongoing
  - Scenario Characteristics Paper
    - » delivered review draft 9/14/99 ✓
    - » expect comments by 9/30/99
    - » plan final 10/15/99

Main Task Schedule Cont'd

- FY00/01 PDs
  - Sample Scenario (CMS format)
    - » delivery date 1/00
  - Sample Trajectory Analysis
    - » completion date 4/00
  - Initial Accuracy Scenario
    - » delivery date 7/00
  - Final Accuracy Scenario
    - » delivery date 11/00

Methodology



Team Assignments

- Bob Oaks
  - Field Data Processing Software
- Mike Paglione
  - Aircraft to Aircraft Encounters
- Hollis Ryan
  - Aircraft to Special Use Airspace Encounters
- Scott Summerill
  - Scenario Metrics

Status of Scenario Generation Task

Field Data Processing Software

Presented by
Bob Oaks

September 29, 1999

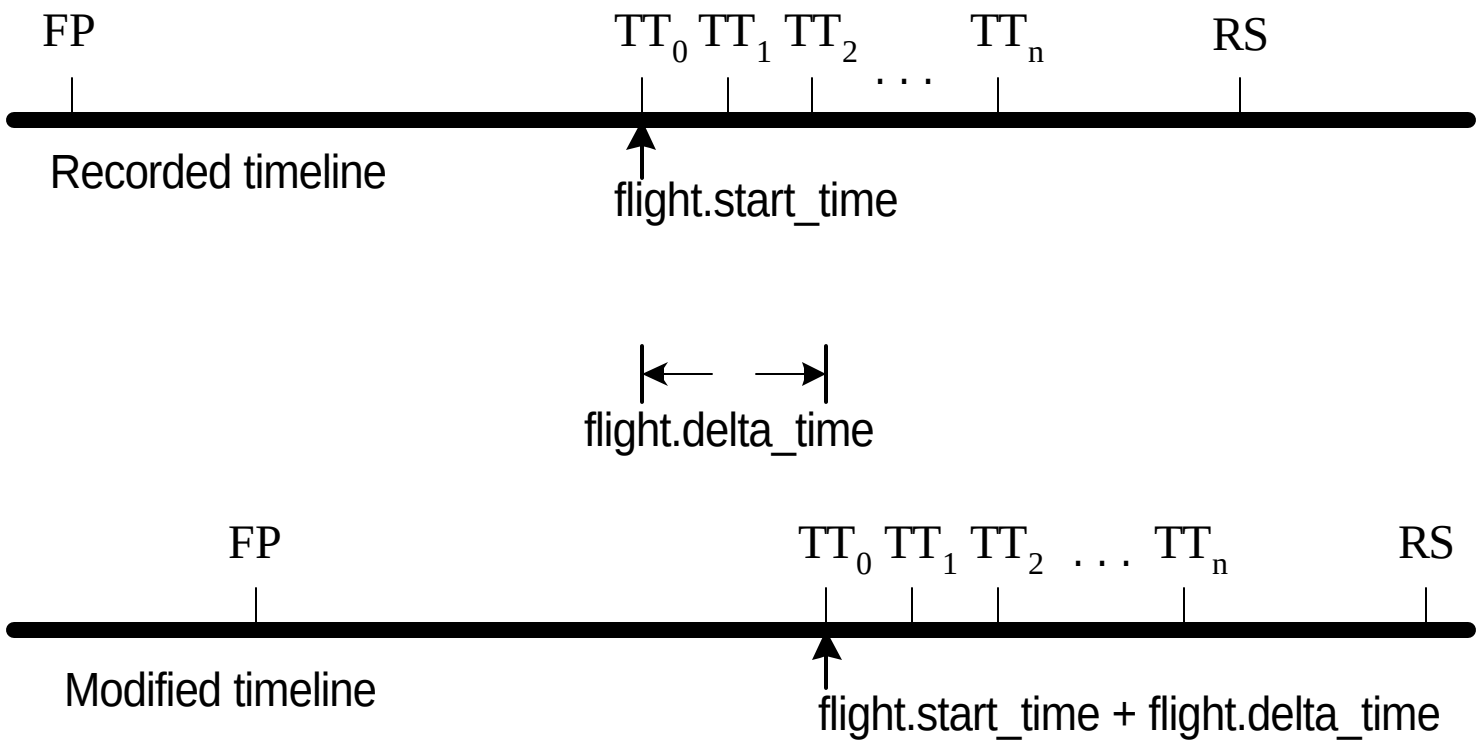
Air Traffic Database

- **Bookkeeping tables**
  - contain data set and run identification information
- **Flight tables**
  - contain flight-centric message data
- **Environment tables**
  - contain center specific data

Flight-Centric Message Data

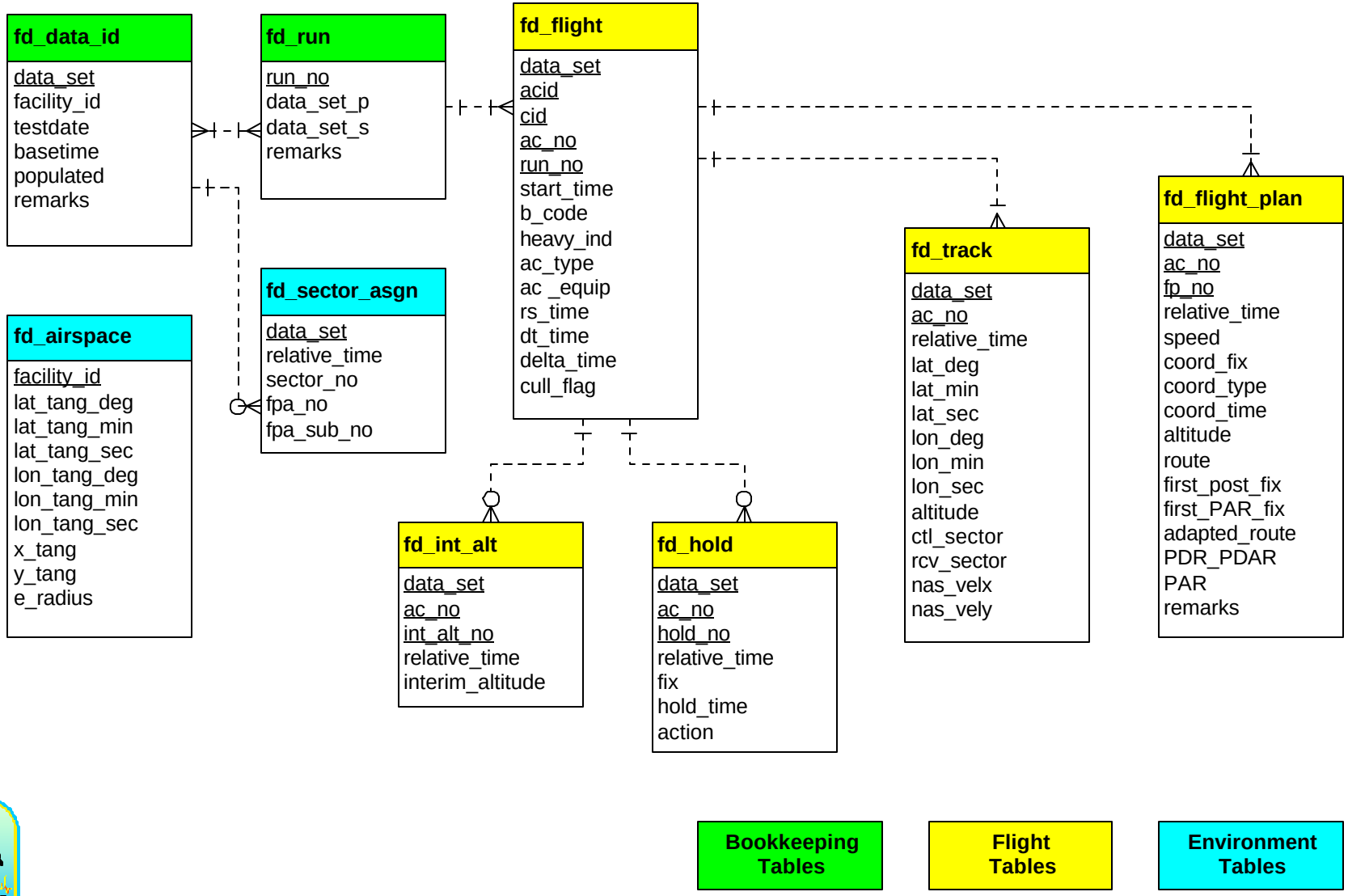
- A flight is established for each unique ACID/CID with a flight plan message.
- Each flight has a *start_time*, which is the time of the flight's first recorded track message.
- All other event times associated with a flight are relative to this *start_time*.
- Each flight also has a *delta_time* which
  - can be adjusted by software to create different scenarios
  - by changing the time events associated with flights.

Example of Modifying a Flight by *delta_time*



Messages shown using P320 message type codes

ER-Diagram of Air Traffic Database



Bookkeeping Tables | **Flight Tables** | **Environment Tables**

The Program *ext*

Extracts message data from a HID recorder file and inserts data into the Air Traffic Database

- C++ program using the Oracle Pro*C/C++ Precompiler
- Uses *pc320fileclass* developed by MITRE
- Assigns the *data_set* number
- Extracts data from a HID recorder file
- Inserts data in the Air Traffic Database
- Establishes the nominal run for this *data_set*

  (i.e., assigns the *run_no* in which *delta_time=0* for each flight)

Sample *fd_flight* Data

DATA SET	ACID	CID	AC NO	START TIME	BEACON CODE	HEAVY IND	AC TYPE	AC EQUIP	RS TIME	DT TIME	RUN NO	DELTA TIME	CULL FLAG
1	N980WM	242	1	-1	1526		AC90	I	42530.453	0	1	0	0
1	N402BF	261	2	-1	1527		C402	A	43670.46	0	1	0	0
1	N28GP	682	3	40938.004	2031	T	H25A	G	2174.434	0	1	0	0
1	AAL445	666	4	41129.059	7050	T	MD80	G	10233.387	0	1	0	0
1	N440JC	160	5	39761.004	1540		LR60	I	0	0	1	0	0
1	N1640	636	6	39533.059	6375	T	H25B	E	1869.388	0	1	0	0
1	UPS396	370	7	39545.463	1605	F	B752	E	860.991	0	1	0	0
1	AMF667	444	8	39569.063	7316		SW4	A	0	0	1	0	0
1	N66634	684	9	39569.063	1677		BE55	I	7833.377	0	1	0	0
...													
1	BTA4006	942	391	44345.593	2561	T	E145	A	2042.856	0	1	0	0
...													

Sample *fd_flight_plan* data

DATA SET	AC NO	FP NO	RELATIVE TIME	SPEED	COORD FIX	COORD TYPE	COORD TIME	ALT	ROUTE
1	391	1	-1841.109	437	ELD	E	1216	330	IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250
1	391	2	-437.133	437	ELD	E	1220	330	IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250
1	391	3	-287.48	437	ELD	E	1220	290	IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250

Sample *fd_track* Data

DATA SET	AC NO	RELATIVE TIME	LAT DEG	LAT MIN	LAT SEC	LON DEG	LON MIN	LON SEC	ALT	CTL SEC	RCV SEC	NAS VX	NAS VY
---	---	---	---	---	---	---	---	---	---	---	---	---	---
1	391	0	33	5	33	92	55	33	29000	~~F	44	299	346
1	391	12.541	33	6	19	92	54	32	29000	~~F	44	300	343
1	391	24.01	33	7	44	92	52	56	29000	~~F	44	303	343
1	391	36.003	33	9	0	92	51	56	29000	~~F	44	304	346
1	391	48.002	33	10	1	92	50	46	29000	~~F	44	305	346
1	391	60.006	33	11	3	92	49	27	29000	~~F	44	305	343
1	391	72.548	33	12	20	92	48	9	29000	44		307	343
1	391	84.001	33	13	29	92	46	50	29000	44		306	339
...													
1	391	1007.975	34	27	12	90	50	45	16200	15		337	284
1	391	1019.972	34	27	27	90	50	17	15700	15	MMM	329	278
1	391	1032.494	34	28	13	90	48	56	15300	15	MMM	326	272
1	391	1043.983	34	29	43	90	47	8	14400	NC		316	266
...													
1	391	1619.976	34	47	22	89	58	13	5000	NC		38	149
1	391	1632.476	34	47	52	89	58	4	4900	NC		30	153

The Program *sgp*

Extracts message data from a HID recorder file and inserts data into the Air Traffic Database

- C++ program using Oracle Pro*C/C++ Precompiler
- Asks what *run_no* to use
- Asks if P320 formatted scenario is desired
- Asks if CMS formatted scenario is desired
- Selects data from Air Traffic Database and generates requested scenario file(s)

P320 Formatted Scenario File

- ASCII file.
- Mutation of HCS 3.20 patch messages
- Defined by MITRE for URET testing
- Used to perform trajectory analysis for recalibration of the URET CCLD SSD

sgp Generated Scenario

```
114824 FP  BTA4006 942 E145 1 A 437 ELD 1216 E 330 'IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250' ' ' T 2561
121148 FP  BTA4006 942 E145 1 A 437 ELD 1220 E 330 'IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250' ' ' T 2561
121418 FP  BTA4006 942 E145 1 A 437 ELD 1220 E 290 'IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250' ' ' T 2561
121905 TK  BTA4006 942 0 -1 44 0 290 0.0 0.0 418.38 373.92 0.0  0.0  0 299.00 346.00 0.0 0.0 0
121917 TK  BTA4006 942 0 -1 44 0 290 0.0 0.0 419.25 374.67 0.0  0.0  0 300.00 343.00 0.0 0.0 0
121929 TK  BTA4006 942 0 -1 44 0 290 0.0 0.0 420.63 376.05 0.0  0.0  0 303.00 343.00 0.0 0.0 0
121941 TK  BTA4006 942 0 -1 44 0 290 0.0 0.0 421.5 377.29 0.0  0.0  0 304.00 346.00 0.0 0.0 0
121953 TK  BTA4006 942 0 -1 44 0 290 0.0 0.0 422.5 378.29 0.0  0.0  0 305.00 346.00 0.0 0.0 0
122005 TK  BTA4006 942 0 -1 44 0 290 0.0 0.0 423.63 379.29 0.0  0.0  0 305.00 343.00 0.0 0.0 0
122017 TK  BTA4006 942 0 44 -1 0 290 0.0 0.0 424.75 380.55 0.0  0.0  0 307.00 343.00 0.0 0.0 0
122029 TK  BTA4006 942 0 44 -1 0 290 0.0 0.0 425.88 381.67 0.0  0.0  0 306.00 339.00 0.0 0.0 0
...
122541 TK  BTA4006 942 0 44 -1 0 290 0.0 0.0 460.25 404.79 0.0  0.0  0 403.00 256.00 0.0 0.0 0
122546 QQ  BTA4006 942 240
122553 TK  BTA4006 942 0 44 -1 0 290 0.0 0.0 461.62 406.16 0.0  0.0  0 402.00 258.00 0.0 0.0 0
...
123129 TK  BTA4006 942 0 15 -1 0 240 0.0 0.0 498.38 432.41 0.0  0.0  0 353.00 294.00 0.0 0.0 0
123137 QQ  BTA4006 942 130
123141 TK  BTA4006 942 0 15 -1 0 240 0.0 0.0 499.51 433.42 0.0  0.0  0 349.00 295.00 0.0 0.0 0
...
123517 TK  BTA4006 942 0 15 -1 0 179 0.0 0.0 519.76 450.68 0.0  0.0  0 345.00 296.00 0.0 0.0 0
123525 QQ  BTA4006 942 110
123529 TK  BTA4006 942 0 15 -1 0 171 0.0 0.0 521.5 451.92 0.0  0.0  0 342.00 286.00 0.0 0.0 0
...
124617 TK  BTA4006 942 0 -1 -1 0 49 0.0 0.0 567.12 474.54 0.0  0.0  0 30.00 153.00 0.0 0.0 0
125308 RS  BTA4006 942
```

Note: Single flight grepped from a P320 scenario file created by *sgp*

MITRE Generated Scenario

```
121147 FP BTA4006 942 E145  1 A  437 ELD         1220 E 330 'IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250' '' T 2561
121421 FP BTA4006 942 E145  1 A  437 ELD         1220 E 290 'IAH./.ELD.ELDTRANS.UJM.UJM3.MEM/1250' '' T 2561
121905 TK BTA4006 942 0 -1 44 0 290 0.0 0.0  418.32  373.87 0.0 0.0 0  299.00  346.00 0.0 0.0 0
121918 TK BTA4006 942 0 -1 44 0 290 0.0 0.0  419.20  374.62 0.0 0.0 0  300.00  343.00 0.0 0.0 0
121929 TK BTA4006 942 0 -1 44 0 290 0.0 0.0  420.58  376.00 0.0 0.0 0  303.00  343.00 0.0 0.0 0
121941 TK BTA4006 942 0 -1 44 0 290 0.0 0.0  421.45  377.24 0.0 0.0 0  304.00  346.00 0.0 0.0 0
121953 TK BTA4006 942 0 -1 44 0 290 0.0 0.0  422.45  378.23 0.0 0.0 0  305.00  346.00 0.0 0.0 0
122005 TK BTA4006 942 0 -1 44 0 290 0.0 0.0  423.58  379.24 0.0 0.0 0  305.00  343.00 0.0 0.0 0
122018 TK BTA4006 942 0 44 -1 0 290 0.0 0.0  424.70  380.50 0.0 0.0 0  307.00  343.00 0.0 0.0 0
122029 TK BTA4006 942 0 44 -1 0 290 0.0 0.0  425.83  381.62 0.0 0.0 0  306.00  339.00 0.0 0.0 0
...
122541 TK BTA4006 942 0 44 -1 0 290 0.0 0.0  460.19  404.73 0.0 0.0 0  403.00  256.00 0.0 0.0 0
122547 QQ BTA4006 942 240
122553 TK BTA4006 942 0 44 -1 0 290 0.0 0.0  461.56  406.11 0.0 0.0 0  402.00  258.00 0.0 0.0 0
...
123129 TK BTA4006 942 0 15 -1 0 240 0.0 0.0  498.32  432.36 0.0 0.0 0  353.00  294.00 0.0 0.0 0
123139 QQ BTA4006 942 130
123141 TK BTA4006 942 0 15 -1 0 240 0.0 0.0  499.45  433.36 0.0 0.0 0  349.00  295.00 0.0 0.0 0
...
123518 TK BTA4006 942 0 15 -1 0 179 0.0 0.0  519.69  450.62 0.0 0.0 0  345.00  296.00 0.0 0.0 0
123527 QQ BTA4006 942 110
123529 TK BTA4006 942 0 15 -1 0 171 0.0 0.0  521.44  451.86 0.0 0.0 0  342.00  286.00 0.0 0.0 0
...
124618 TK BTA4006 942 0  0 -1 0  49 0.0 0.0  567.05  474.48 0.0 0.0 0   30.00  153.00 0.0 0.0 0

125313 RS BTA4006 942
```

Note: Single flight grepped from a P320 scenario file created by MITRE tools

CMS Formatted Scenario File

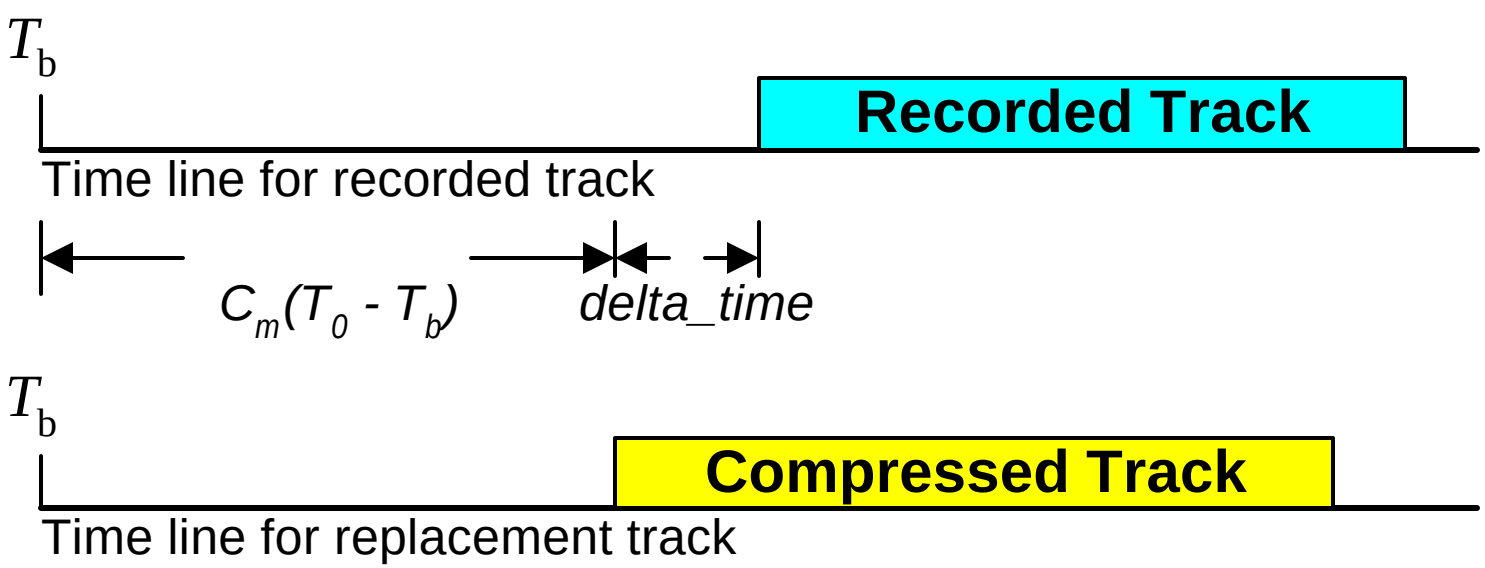
- Determined P320 HID recorder file format
  - Worked with MITRE
  - Provided this information to LMATM
- LMATM opened SIG 264 to specify its contents and format
  - ACT-250 is a member of the Concurrent Engineering Team
  - Draft received for peer review
- File containing a hodgepodge of:
  - ASCII encoded headers
  - Binary data
  - EBCDIC encoded messages
- Using IRD dated August 23rd plus RPRs to be specified by LMATM

The Program *Odo*

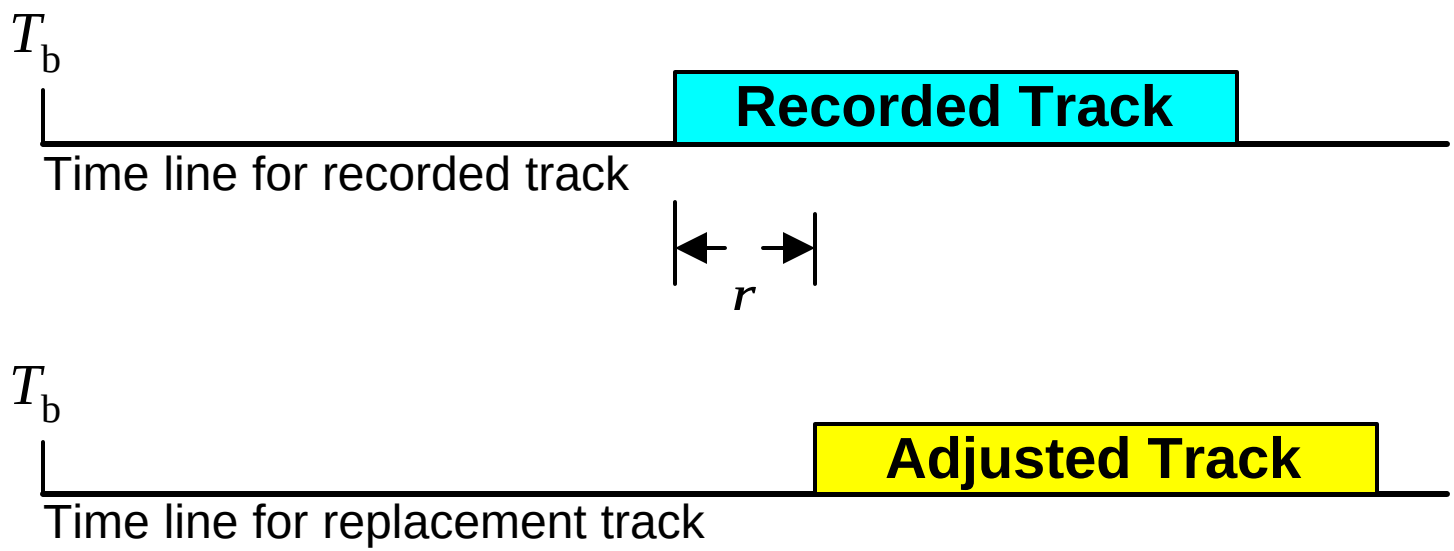
Creates runs using time shifting

- Asks what *data_set* (or *data_sets*) to use in run
  - » Primary data set is center under test
  - » Secondary data set is its interfacility center
- Assigns *run_no*
- Creates *fd_flight* entries from those *data_sets*
  - » with that *run_no*
  - » with *delta_time* modified
- The *delta_times* are modified by:
  - » scenario time compression
  - » random time adjustment

Scenario Time Compression



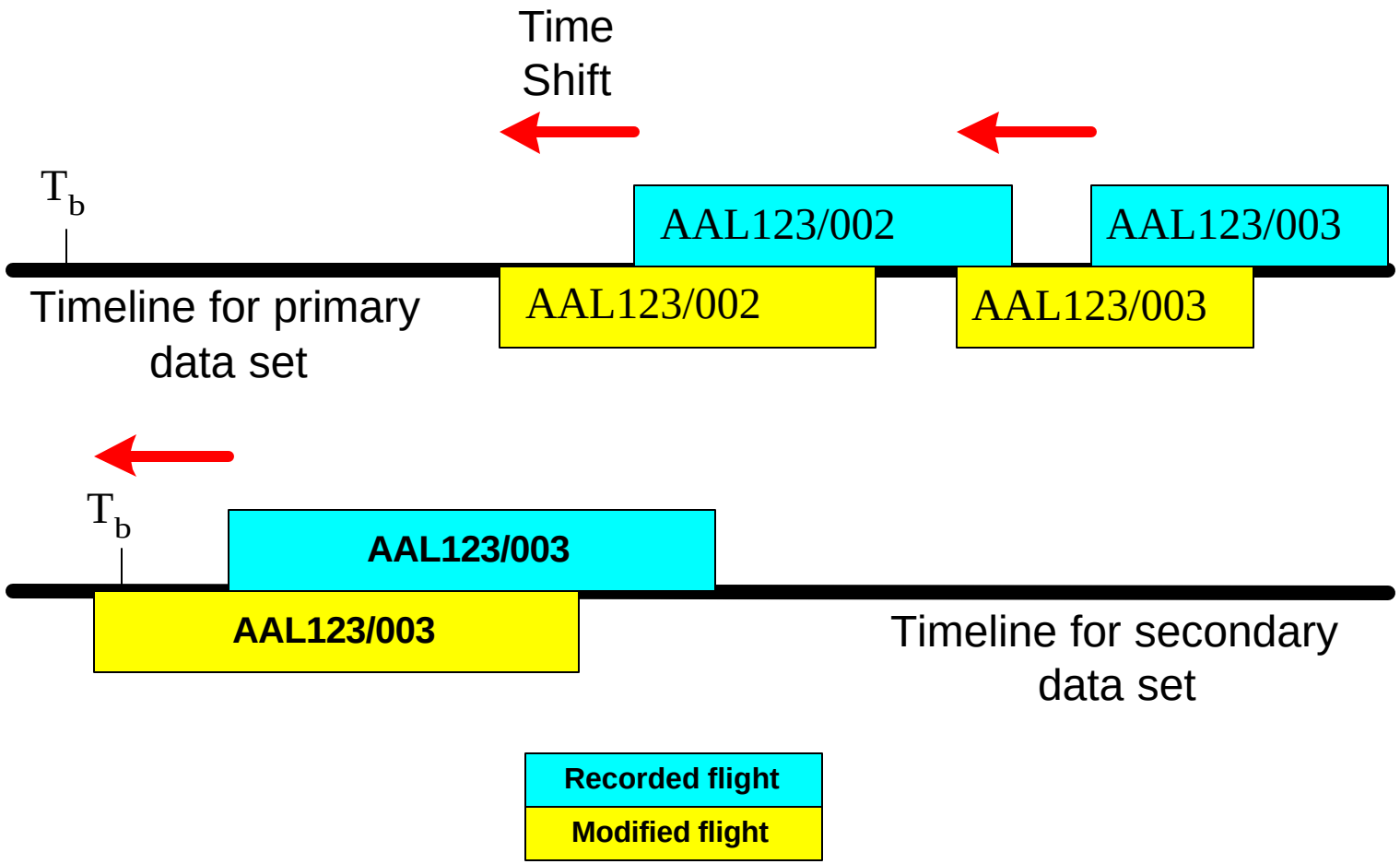
Random Time Adjustment



Comments About Modifying Time

- For scenario time compression
  - 10% compression means $C_m = 0.9$
- For random time adjustment
  - pseudorandom variable optionally generated from:
    - » normal distribution
    - » uniform distribution
    - » Combination of these techniques can produce an acceptable number of conflicts
- For both techniques
  - *delta_time* for a specific ACID is kept constant within both the primary and secondary data sets.

Modifying Interfacility Flights



Next Steps

- Add CMS scenario generation to *sgp*
  - Done incrementally
  - Requires good working relationship with LMATM
  - May result in additional data items in existing tables
  - May result in additional tables
- Interface "modify field data" process with trajectory accuracy processes
  - Genetic Algorithm can modify flight start times to produce conflicts with desired distribution of characteristics
- Verify and validate
- Document processes (Methodology Paper)

Status of Scenario Generation Task

Aircraft to Aircraft Encounters

Presented by

Mike Paglione

September 29, 1999

Definition of Aircraft to Aircraft Encounter & Conflict

- For encounter, aircraft pair separated by:
  - less than 30 nm horizontally
  - less than legal separation vertically

    (i.e. 1000 ft at or below FL 290 and 2000 ft above)
- For conflict, aircraft pair separated by:
  - less than 5 nm horizontally
  - less than legal separation vertically

    (same as encounter)

Design Considerations in Encounters/Conflicts

- Encounter Exceptions
  - Encounter ends but resumes within 5 minutes or less, is considered single encounter
  - Encounter with track time gap is considered single encounter if it resumes within 5 minutes or less
  - Exclude encounters with duration of ≤ 10 seconds
  - Aircraft in cruise assumed at assigned altitude for separation calculations if within 300 ft of assigned altitude

Design Considerations in Encounters/Conflicts Cont'd

- Flight Plan Adherence
  - lateral adherence age calculated using reference time based on constraint table (*Table 3.2-1 and 3.2-2) where minimum horizontal separation falls
  - thresholds vertical flight plan adherence in SSD and thresholds for lateral flight plan adherence being evaluated

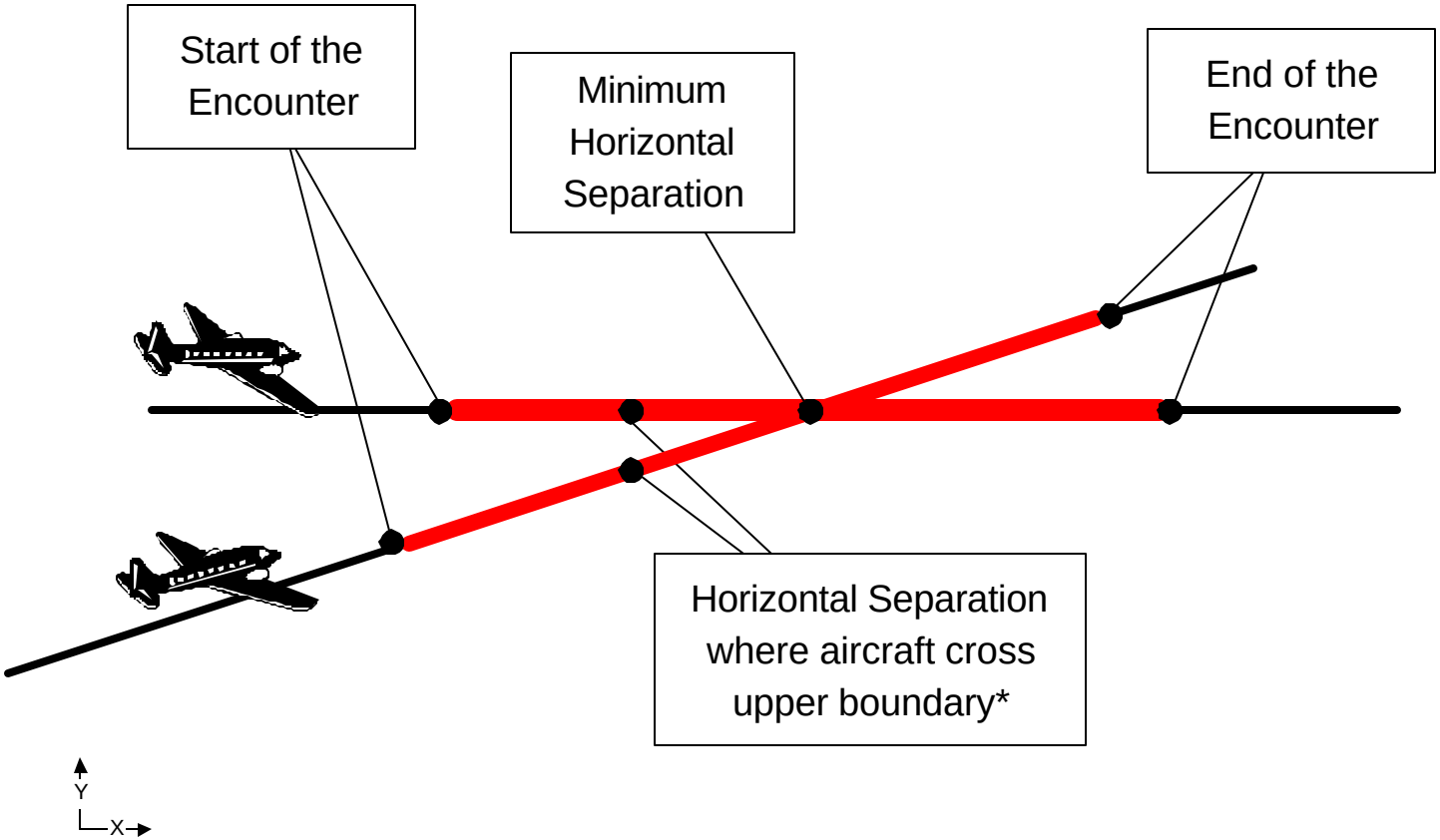
*Source: *Description of Accuracy Scenarios for the Acceptance Testing of URET CCLD*, Review Draft 9/14/99

Table 3.2-1: Current Plan Aircraft to Aircraft Encounter Counts*

Minimum Horizontal Separation (nm)	Total Number of Encounters Required
0 <= d < 5	506
5 <= d < 10	506
10 <= d < 15	506
15 <= d < 23	506
23 <= d < 30	506

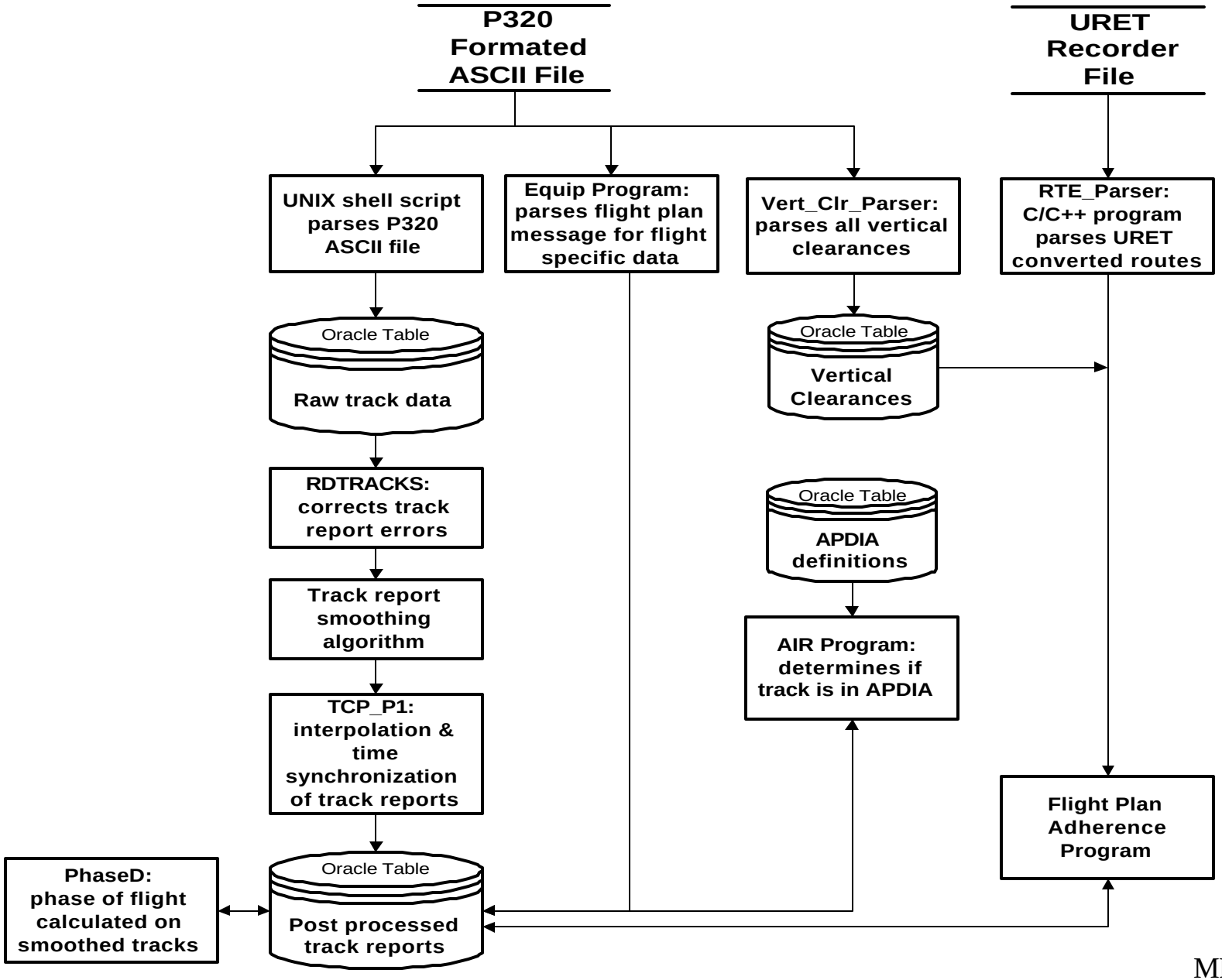
*Source: *Description of Accuracy Scenarios for the Acceptance Testing of URET CCLD*, Review Draft 9/14/99

Example Encounter & Lateral Adherence



*Upper boundary found in Table 3.2-1 and 2 in *Description of Accuracy Scenarios for the Acceptance Testing of URET CCLD*, Review Draft 9/14/99

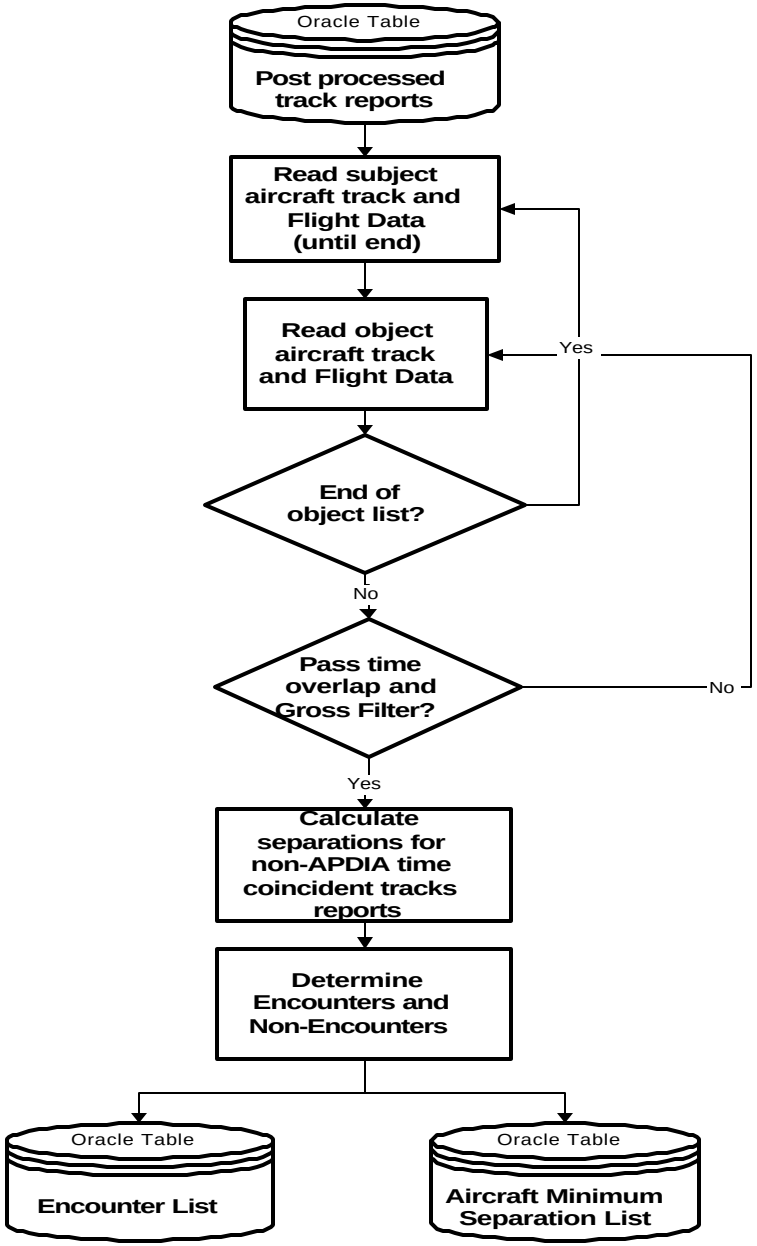
Scenario Processing&Parse URET Data



Track Conflict Probe (TCP)

- Input: Post Processed Track Reports
- Process: Next Slide
- Output: Two Oracle Database Tables
  - Encounter List - lists encounter information
    - » aircraft pair identification
    - » encounter start and end times (XYZT)
    - » adherence age at reference time
    - » minimum separations and their times
    - » encounter angle and phase of flight
  - Aircraft Minsep List - lists pairs that simply passed Gross Filter (around entire flight 35nm & 3000ft)
    - » minimum separations and their times
    - » altitude at minimum horizontal separation

TCP Process


Oracle Table
Post processed track reports
Read subject aircraft track and Flight Data (until end)
Read object aircraft track and Flight Data
Yes
End of object list?
No
Pass time overlap and Gross Filter?
No
Yes
Calculate separations for non-APDIA time coincident tracks reports
Determine Encounters and Non-Encounters
Oracle Table
Encounter List
Oracle Table
Aircraft Minimum Separation List

Next Steps

- Finalize Scenario Characteristics Paper
- Flight Plan Adherence
  - Develop software tools
    - » Parse route conversion ✓(complete)
    - » Calculate lateral adherence
    - » Parse vertical clearances
    - » Calculate vertical adherence
  - Analysis of thresholds
  - Incorporate in Characteristics Paper or Addendum
- Track Conflict Probe (TCP)
  - Re-code in Oracle Pro C / C++ from current Oracle PL / SQL (for speed)
  - Validate / Verify
  - Incorporate in overall tool set
  - Document into Methodology Paper

Status of Scenario Generation Task

Aircraft to Special Use Airspace Encounters

Presented by
Hollis Ryan

September 29, 1999

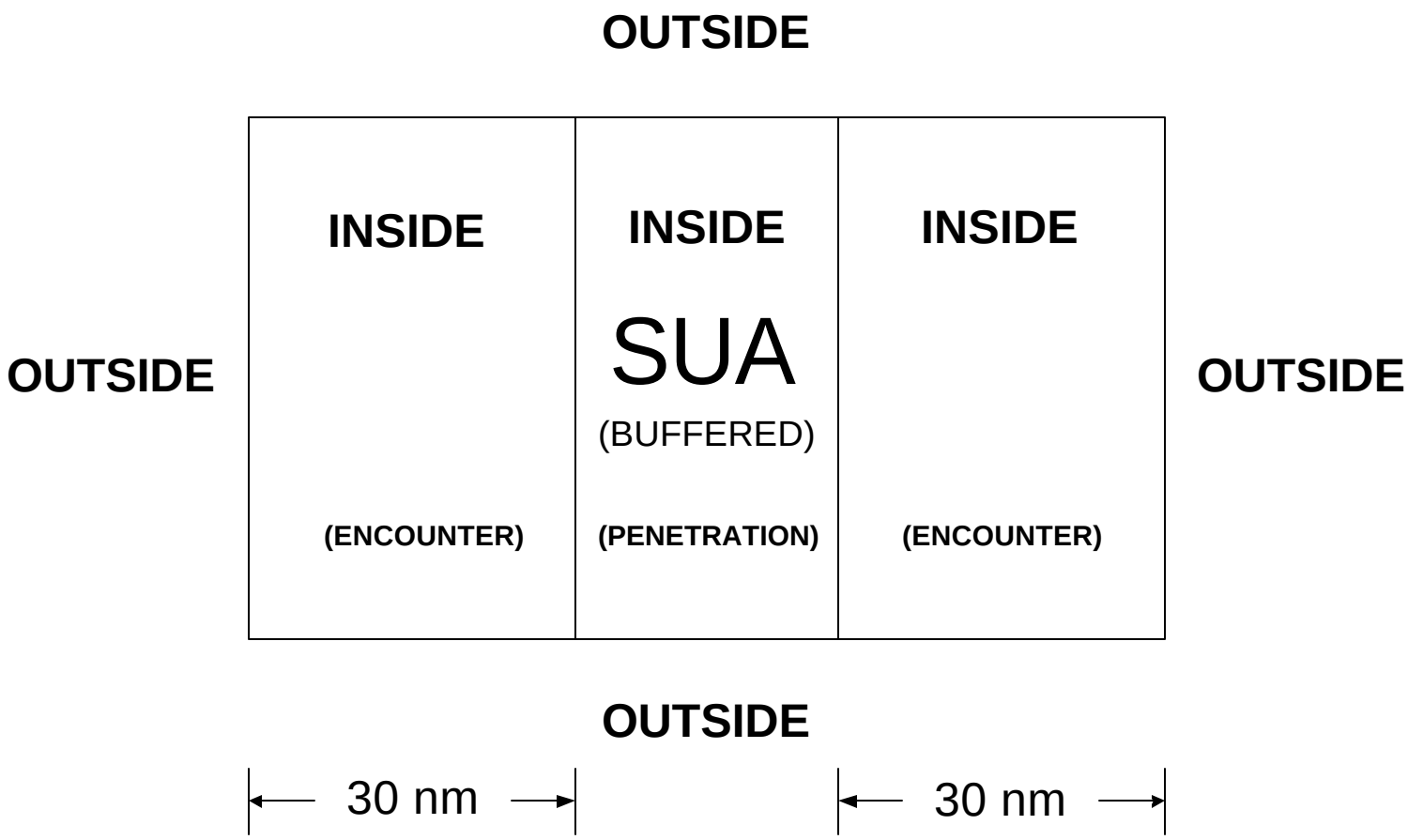
A/C Encounters - SUAs

- SUA = Special Use Airspace
- Scenario(s) will provide required number of encounters between aircraft and SUAs
- ZME has 38 SUAs
- Synthetic SUAs added as necessary

Special Use Airspace

- 3 dimensional object
- Active or inactive over time
- Vertical sides
- Projection onto horizontal plane is a polygon
- Adaptation data (from MITRE)
- Boundaries expanded

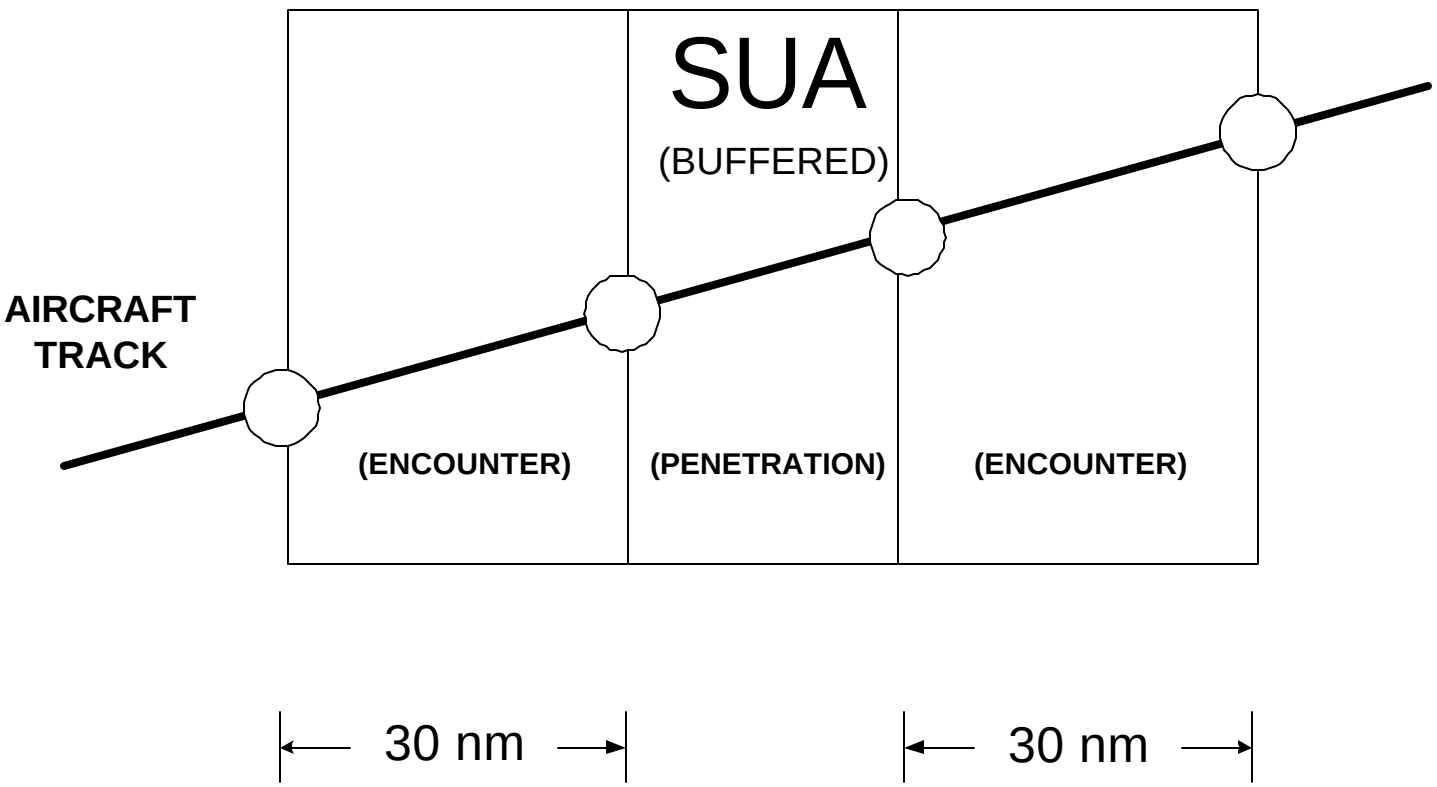
ENCOUNTER GEOMETRY



ENCOUNTERS & PENETRATIONS - SUA
SIDE VIEW

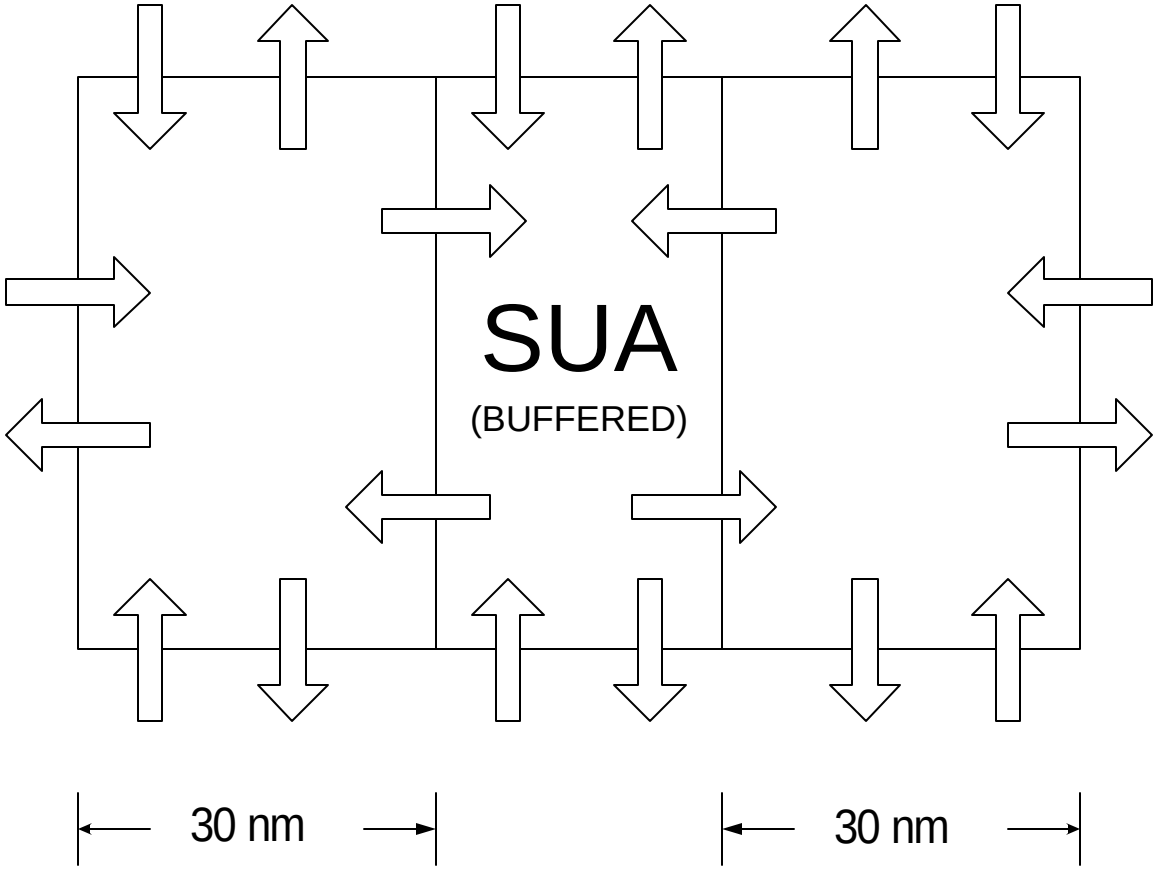
ENCOUNTER GEOMETRY

BOUNDARY CROSSINGS:



ENCOUNTERS & PENETRATIONS - SUA
SIDE VIEW

ENCOUNTER GEOMETRY



ENCOUNTERS & PENETRATIONS - SUA
SIDE VIEW

Types of Encounters

- **Non-Penetrating Encounter**
- **Penetrating Encounter**

Note: An aircraft track may start and/or end inside the encounter airspace.

Non-Penetrating Encounter

- Aircraft ID
- SUA ID
- Minimum Horizontal Separation (Value & Time)
- Minimum Vertical Separation (Value & Time)
- Minimum Max-Ratio (Value & Time)
- Start of Encounter (XYZT)
- End of Encounter (XYZT)
- Adherence Age
- Aircraft Characteristics
  - Flight type
  - A/C type
  - Equipage
  - Phase of flight

Penetrating Encounters

- Same as for Non-Penetrating Encounters
- Penetration Count
- Start of First Penetration - XYZT
- End of Last Penetration - XYZT
- Encounter Angle

Note: The minimum horizontal and vertical separations are defined to be zero.

Table 3.2-3: Current Plan Aircraft to Airspace Encounter Counts*

Minimum Horizontal Separation (nm)	Required Encounters
0 <= d < 7	506
7 <= d < 9	506
9 <= d < 11	506
11 <= d < 16	506
16 <= d < 30	506

*Source: *Description of Accuracy Scenarios for the Acceptance Testing of URET CCLD*, Review Draft 9/14/99

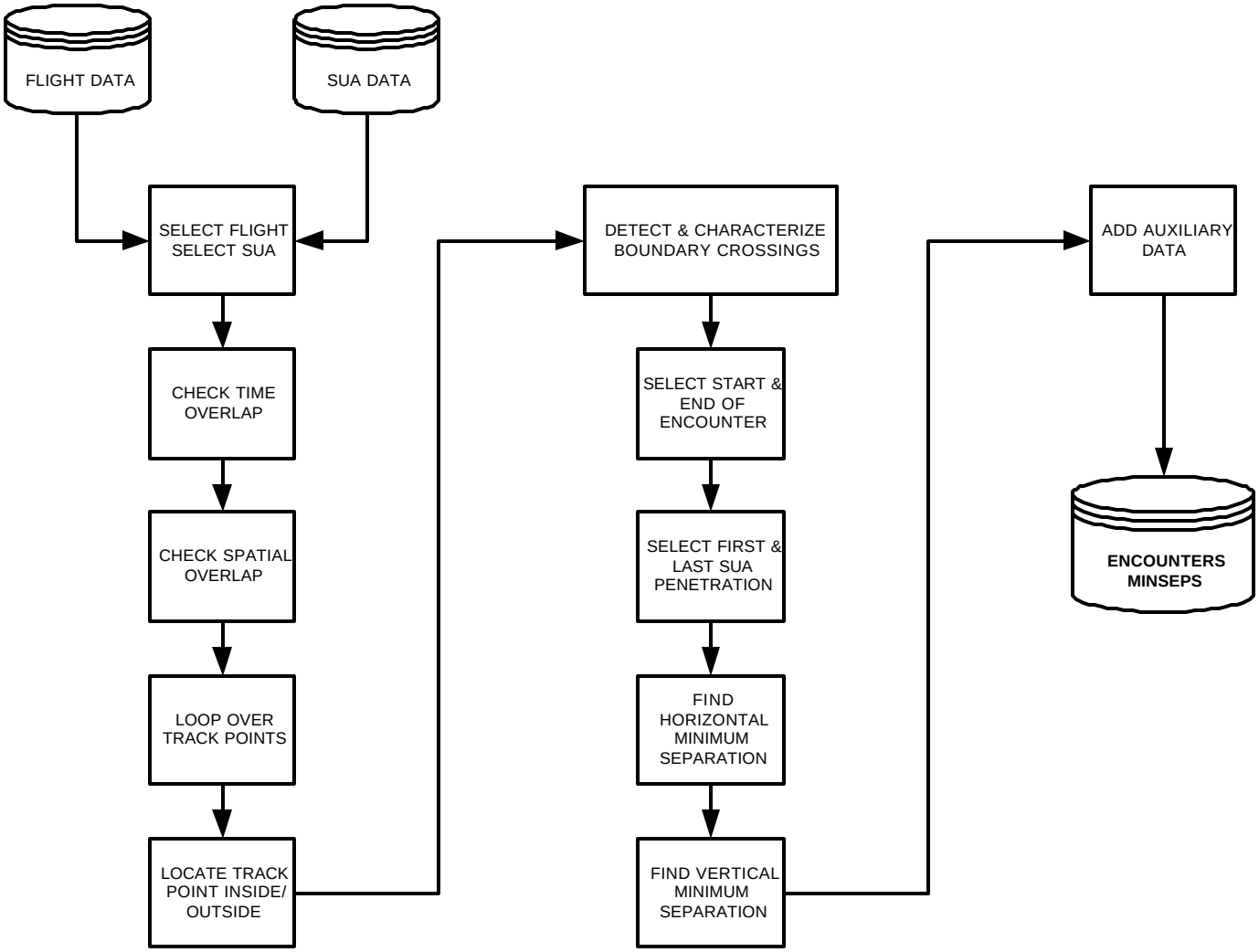
Review of Scenario Processing of A/C Tracks

- Glitch removal by RDTRACKS program
- Interpolation to 10 second samples
- Time shifted
- Characterization
  - Flight type
  - Aircraft type
  - Equipage
  - Phase of flight at CPAs

Program suas_pen

- **Inputs: (Oracle Database Tables)**
  - **SUA coordinates**
  - **Aircraft tracks including ancillary data**
- **Process: See Next Slide**
- **Outputs: (Oracle Database Tables)**
  - **Encounters**
  - **Minimum separations**

Flowchart for Program suas_pen



Program Elements Implemented

- Read SUA & Aircraft Track Data from Oracle Databases
- Add Buffer Spaces to SUAs
- Gross Filter - Tracks & SUAs
- Approximate SUA by Enclosing Cylinder
- Find Starts & Ends of Encounters
- Find Penetrations - Entrances & Exits
- Find Minimum Horizontal Separations
- Extract Flight Characteristics for Encounters
- Counts
- Output to ASCII Data Files

Next Steps

- Complete implementation
  - Adjust Aircraft Level Cruise Altitudes
  - Calculate Minimum Distance to SUA Boundary
  - Determine Inside/Outside of Polygons
  - Merge Encounter Segments
  - Calculate Encounter Angles
  - Output to Oracle Database
- Verify & Validate code
- Run program on ZME data
  - Empirically add synthetic SUAs
- Document