Distributed Schemes for Integrated Arrival Departure and Surface Scheduling

Arrival and Departure Interactions at Five Major Airport / Metroplex Environments

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January 9, 2015

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Preface

This document is a description of interactions between arrival and departure flows at five major airport or metroplex environments. This report presents background descriptions of these interactions, including diagram depictions and discussion of inefficiencies. This background information will be used in further analysis, subject matter expert elicitation, and collaboration with NASA for the down selection of the real-world problems to use for the modeling and simulation. This document was prepared by Engility Corporation, 900 Technology Park Drive, Suite 201, Billerica, MA, under NASA Research Announcement (NRA) Contract Number NNA14AB46C. It represents the deliverable "Report on the identification of 3 real-world problems involving arrivals and departures and in the surface and performance metrics" for the NRA titled "Distributed Schemes for Integrating Arrival Departure and Surface Scheduling".

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Introduction

As the traffic congestion in the National Airspace System (NAS) increases, the interaction between the different traffic flows which compete for limited resources increases. This interaction is more pronounced at and around airports, where arrival and departure flows often intersect in the terminal airspace and on the airport surface. While the norm in managing these flows has been to segregate them procedurally, the increase in demand and congestion is necessitating more sharing of limited resources such as the runways and increasingly the airspace fixes and routes. Hence, there is an increased need for traffic management solutions that integrate these arrival, departure, and surface operations.

This research effort, entitled "Distributed Schemes for Arrival Departure and Surface Scheduling", will attempt to identify solutions for integrating the scheduling of arrival, departure, and surface operations in one airport and in metroplex (multiple airports in close proximity) systems. This report describes a first step towards selecting real-world problems that feature interactions between arrival and departure flows at major airports. The real world problems will support the development and analysis of concepts for integrated scheduling of arrival and departure operations on the airport surface and in the terminal airspace surrounding the airport.

The first step of the selection was to identify interactions between arrivals and departures at five airport or metroplex environments. Five environments were identified based on consultation with NASA. This report presents background description of the arrival-departure interactions at these sites based on site visits, review of standard procedures, and past studies where available. The descriptions include diagram depictions and discussion of inefficiencies, along with potential areas for the application of integrated scheduling solutions. This background information will be used in further analysis, subject matter expert elicitation, and collaboration with NASA for the down selection of the real-world problems to use for the modeling and simulation.

The report starts with a listing of the airports analyzed and the selection criteria. Then a description of the arrival-departure interactions for each airport/metroplex is given in five separate sections.

Airports Analyzed

Five sites were selected for analysis in this report based on feedback from NASA:

1. The New York metroplex N90
2. Atlanta (ATL)
3. Charlotte (CLT)
4. The Northern California metroplex (NoCal)
5. The Southern California metroplex (SoCal)

The criteria for the selection were as follows:

The New York metroplex N90 was mandated by the statement of work as a site to include in the analysis because of its importance as a choke point in the NAS and the complexity of the interactions between its flows.

One metroplex on the west cost was desired; hence the NoCal and SoCal metroplexes were analyzed as candidates.

CLT is a site that NASA has been considering for conducting demonstrations of departure scheduling and metering tools. Hence, it was desired to analyze CLT as a candidate for potential follow on research that extends the current activities to the integration of arrival and departure scheduling.

ATL was selected as a candidate site because of its high traffic volume, modern design, and hub-type operations, in order to provide a contrast to the more constrained environments such as N90.

While only five sites were analyzed in this report, additional sites may be included for the final analysis and selection if desired. For example, Dallas Fort Worth (DFW) was also proposed as a candidate that is similar to ATL in terms of operations, with the advantage of the existence of considerable past NASA research on the site. DFW was not analyzed in this report; rather ATL was selected because it ranks higher in terms of volume of operations and as a choke point in the NAS generating considerable delay. DFW and other sites may be included in the final analysis if needed or desired.

Analysis Methodology

The analysis of the five sites was based on the following activities, some of which are completed and some are continued because they are needed for the final selection:

1. Site visits were conducted to ATL (control tower and TRACON facilities) and to New York, including Laguardia (LGA), Newark (EWR), and Kennedy (JFK) Towers, providing perspectives on different types of operations. The knowledge about the arrival-departure interactions and issues that was gained from these visits was leveraged in the analysis of the other airports as well.

2. Review of standard operating procedures either obtained from the facilities or available online.

3. Review of the Optimization of Airspace and Procedures in the Metroplex (OAPM) study reports [1]. These reports were available (online) for CLT, ATL, and NoCal. These reports concentrated on issues and improvements related to either arrival flows or departure flows. However, they contained relevant background information and analyses of the traffic flows, standard arrival and departure procedures, and airspace design.

4. Solicitation of subject matter expert (SME) input was performed in a limited manner during the site visits mainly. Therefore, some of the interactions identified in this report, which are based mostly on interpretations of the available documents and studies, will require adjustment and refinement based on further SME feedback. Additional SME input will be elicited towards the final selection.

5. Data analysis is needed in order to quantify the interactions and associated inefficiencies that are identified from the reports and from SME input. Due to the wide scope of the interactions, data analysis will be used mainly for the down selection of cases and will be presented in the final report as part of the selection of the final cases. In preparation for this, a list of issues related to arrival-departure interactions in the airspace and on the surface was generated along with associated metrics to quantify their effects. The following two tables include these lists for a single airport and for a metroplex, respectively. This list is rather comprehensive and was generated independently of whether it will be possible to produce all the metrics. In the down selection of the cases a subset of these metrics or variations on them will be used as needed and deemed feasible.

Table 1. Airport issues and metrics

Airspace and Airport Issues	Possible Metrics
Intersection between climbing and descending flows leading to inefficient leveling off or excessive vectoring	- Amount of level off and associated fuel burn and delay - Amount of vectoring and associated fuel burn and delay
Difficulty in merging departures into departure fixes and overhead streams leading to delays on the surface or excessive vectoring	- Delay of departures inserted into congested streams/fixes
Imbalance in fix loading leading to restrictions on some fixes while capacity exists on other fixes	- Relative traffic load on arrival and departure fixes - Relative restrictions on arrival and departure fixes
Lack of route and stacking options for arrivals and departures leading to excessive spacing on available routes	- Spacing along arrival and departure routes and at fixes, relative to minimum required spacing - Variability in altitude near arrival and departure fixes
Lack of airspace sharing leading to long routes for arrivals and departures	- Excess travel distance and time along arrival and departure routes relative to shortest path
lack of ability to balance runway usage between arrivals and departures such as switching a runway from arrivals to departures or vice versa based on demand	- Frequency of configurations with same flow direction but different runways for arrivals and departures - Variability in arrival and departure rates within same flow direction
Crossing runways or close parallel runways leading to dependency between arrival and departure runway operations and the difficulty in efficiently creating gaps between arrivals to accommodate departures	- Frequency of use of crossing or close parallel runways for arrivals and departures - Correlation between arrival and departure rates (Slope of Parito capacity envelope)
Arrivals crossing of departure runways while taxiing leading to interruption in the departure flow and adding to the arrival taxi in delays	- Frequency of configurations with arrivals crossing departure runways - Arrival taxi in time delay due to runway crossing
Difficulty in conforming to takeoff restrictions for example due to lack of staging areas by the runway end	- Conformance to restrictions
Difficulty in meeting user concerns and preferences in sequencing arrivals and departures and assigning runways, for	- Frequency of runway reassignment by the TRACON or Tower - Frequency of runway assignment based on

example based on gate location or flight delay	gate location
High traffic volume relative to capacity leading to excessive congestion and long queues	- Amount of departure queuing - Amount of throughput saturation
Limited amount of taxiways and staging areas to accommodate long departure queues leading to quick gridlock	- Amount of arrival taxi in delay due to departure queues - Amount of departure congestion on the taxiways outside the runway queues or amount of aircraft on the taxiways relative to available holding capacity of the taxiways
Lack of gates and ramp space and short turnaround times leading to difficulty in holding departures at the gates or ramp for departure metering	- Frequency of connecting flights in a day - Statistics of turnaround time and gate occupancy
Difficulty in creating the desired runway sequence due to lack of taxiways and control points for sequencing	- Statistics of the frequency of resequencing between the pushback order and takeoff order for departures and between the TRACON entry and landing for arrivals - Statistics of the gaps between arrivals that are larger than a whole number of departures and associated lost capacity
Degree of overlap between scheduled arrival and departure operations	- Statistics of the relative number of arrival and departure scheduled flights in each time period
Interaction between the taxiways and ramp areas leading for example to blockage of entry/exit to/from the ramp and blockage of taxi segments by pushback or waiting aircraft	- Frequency of taxi segment blockage - Frequency of pushback onto taxiways

Table 2. Metroplex issues and metrics

Metroplex Issues	Possible Metrics
Loss of ability to use a runway due to other airport configurations	- Frequency of configurations with lost runway due to another airport configuration - Estimated lost capacity
Intersections between flows resulting in the need to create gaps in the flows and lost throughput	- Frequency of configurations that result in intersecting flows - Lost capacity due to intersecting other flows
Longer arrival or departure routes to avoid other airport airspace	- Excess travel distance relative to shortest path - Delay relative to shortest path
Sharing of departure fixes among departures from different airports	- Delay of departures inserted into congested streams/fixes
Intersections between climbing and descending flows resulting in capping and tunneling of flows and inefficient level offs	- Amount of level off and associated fuel burn - Amount of vectoring and associated delay
Limited ability to vector and absorb delay due to constraints from neighboring airports' airspace	- Statistics of the delay and excess distance relative to procedure routes - Statistics of the frequency of control activity such as passing between the TRACON boundary and the runways
Lack of routes resulting in single climb headings and inability to use divergent heading separations	- Variability in headings off the runway - Estimated lost capacity

The New York N90 case

The main sources of the analysis of the New York case are navigation routes and SOPs available online [5] and observations and SME input during site visits conducted in December 2014. Further SME input will be obtained to confirm or adjust this analysis.

Interactions between arrivals and departures are highlighted under the following categories:

a. Airspace interactions
b. Runway interactions
c. Taxi and ramp interactions

Airspace interactions

The following interactions were identified based on the site observations and review of SOPs:

1. There are interactions between the configurations used at the three major airports: JFK, EWR, and LGA as explained in the SOP excerpt in Figure 1.

N90 Airport Interaction Chart

JFK	LGA	EWR
ILS 13 *(for winds or weather)*	ILS 13 *(due to airspace constraints)* Runway 13 departures must fly runway heading (Flushing Climb)	On SW flow, TEB may do VOR/DME runway 24
		On NE flow, TEB departures maintain 1,700'. EWR departures fly runway heading to 4 DME
Any approach to runway 4L/R or VOR 22L	Runway 13 departures: Whitestone and Coney Climbs	All the following pertains to EWR departing runway 22L/R. Owns 6,000' to SUL
	Maspeth Climb	Climbs 1 1/2 nm from SUL
ILS 22 Owns Belmont airspace 3,000' and below	ILS 22 required if departing runway 13. Flushing Climb: Props only Maspeth and Coney Climbs: All types If on runway 4, can not depart runway 13	Climbs 1 1/2 nm from SUL
Must be on runway 31L/R if:	LOC 31	Climbs 1 1/2 nm from SUL
	Runway 4, Expressway 31, River 13	Climbs 3 nm from SUL

Figure 1. N90 airport interaction chart [5]

Most of the interactions involve LGA, because of its location between EWR and JFK. Hence the analysis will concentrate on LGA for explanation. The main reasons for these interactions are the corresponding airspace delegations which are explained in the following SOP excerpts in Figure 2. These interactions are explained as follows:

a. When LGA lands LOC 31, JFK releases airspace areas 25/26/27 to LGA and is forced to land on 31L/R. However, according to the feedback from the site visits, landing on 31L/R is the second best landing configuration for JFK after landing 13L/R and hence the impact is not drastic on JFK.

Airspace Delegation

Block	Unconditional	Conditional
1	NONE	10,000 for arr via LIZZI
2	NONE	11,000 / 10,000 for arr via LIZZI
3	10,000	NONE
4	10,000 / 9,000	NONE
5	10,000 / 8,000	NONE
6	10,000 / 7,000	NONE
7	9,000 / 8,000	NONE
7a	9,000	NONE
8	9,000 / 8,000	HAR by ZDC thru 10,000
9	8,000 / 7,000	NONE
10	7,000	NONE
11	NONE	10,000 / 7,000 when EWR **NOT** Dep 22L/R
12	NONE	10,000 / 4,000 when EWR **NOT** Dep 22L/R
13	10,000 / 3,500	NONE
14	10,000 / 3,500	Traffic 10,000 / 7,000 must remain 1.5 nm EAST of SUL, traffic below 7,000 must remain 3 nm EAST of SUL
15	10,000 / BELOW	10,000 / 4,000 when rlsd TO JFK for ILS Rwy 13L
16	NONE	5,000 / 4,000 when rlsd BY JFK for Coney Climb *Coney Airspace*
17	NONE	10,000 / 2,500 when rlsd BY JFK for Coney Climb *Coney Airspace*
18	NONE	12,000 / 1,500 when rlsd BY JFK for Maspeth / Coney Climbs *Coney Airspace*
19	12,000 / BELOW	12,000 / 4,000 when rlsd TO JFK for ILS 13L
20	15,000 / 11,000	NONE
21	15,000 / 9,000	NONE
22	15,000 / 7,000	NONE
23	12,000 / BELOW	NONE
24	12,000 / BELOW	12,000 / 4,000 when rlsd TO JFK for ILS Rwy 22L/R
25	NONE	3,000 / 1,000 when rlsd BY JFK for *LOC 31*
26	NONE	4,000 / 1,000 when rlsd BY JFK for *LOC 31*
27	NONE	4,000 / 2,000 when rlsd BY JFK for *LOC 31*; NOTE: 4,000 / 3,000 when FRG ILS 14 in use
28	6,000 / BELOW	NONE
29	8,000	NONE
30	15,000 / 8,000	NONE
31	15,000 / 7,000	NONE
32	15,000 / 5,000	NONE
33	15,000 / 7,000	3,000 / 2,700 OR 2,000 / 1,800 when rlsd BY EWR for ILS/DME 13
34	15,000 / 6,000	SAME AS AREA **33**
35	15,000 /3,000	2,000 / 1,800 when rlsd BY EWR for ILS 13
36	15,000 / BELOW	15,000 / 3,000 when rlsd TO EWR for TEB VOR 24
37	15,000 / BELOW	NONE
38	10,000 / BELOW	NONE
39	7,000 / 6.000	NONE
40	7,000 / 4,000	NONE
41	11,000 / BELOW	NONE
42	5,000 / BELOW	NONE
43	5,000 / BELOW	5,000 / 4,000 when rlsd TO LIB for SWF ILS 27
44	5,000 / BELOW	5,000 / 4,000 when rlsd TO LIB for SWF ILS27 &/or N69 traffic
45	5,000 / BELOW	5,000 / 4,000 when rlsd TO LIB for N60 apchs/depts.
46	3,000 / BELOW	ISP owns 3,000 / BLO east of dashed boundary when rlsd as OXC block
47	9,000 / BELOW	NONE

Figure 2. N90 LGA airspace delegations [5]

b. When JFK lands ILS 22L/R, the Belmont airspace (which includes area 24 in addition to 25/26/27/28) is released to JFK, which puts restrictions on the LGA departure climbs as depicted in Figure 1 (essentially losing the left turn off runway 13). However, according to the observations during the site visits, the TNNIS RNAV climb was created to mitigate this problem and enable left turns off LGA runway 13 despite the Belmont airspace delegation. This is indicated in the following excerpts from the SOP in Figure 3 showing the Belmont airspace and Figure 4 depicting the LGA climbs off runway 13 and its restrictions.

[Potential application: Further SME input is needed to confirm if, with the introduction of the RNAV climb, these restrictions remain an issue that is worth analyzing. It is possible that sharing the Belmont airspace between JFK arrivals and LGA departures with scheduling can mitigate any remaining issues.]

Belmont Airspace Extension

LaGuardia Area, with coordination, shall delegate an extension of the Belmont airspace at and below 3,000' to the Kennedy Area when all of the following conditions exist:

- Weather is IMC
- JFK is landing both ILS 22L/R approaches
- LGA is landing ILS 22 and departing runway 13 (other than Flushing climb)
- HPN is landing and departing runway 16

Note: LaGuardia Area should retain this airspace when landing runway 22 and departing runway 31, or when HPN is landing runway 34.

(See LGA-JFK LOA 2(b)).

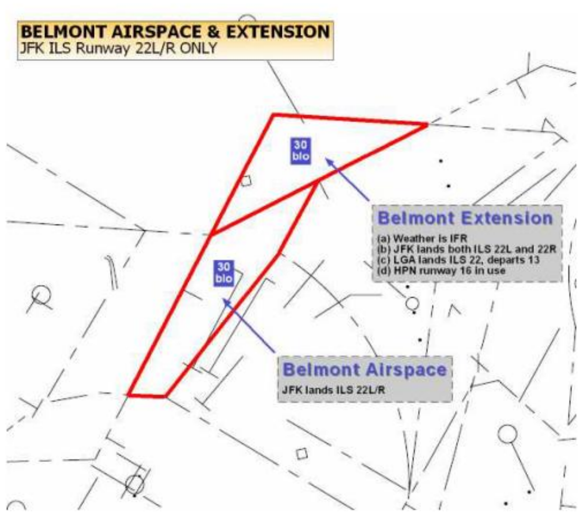


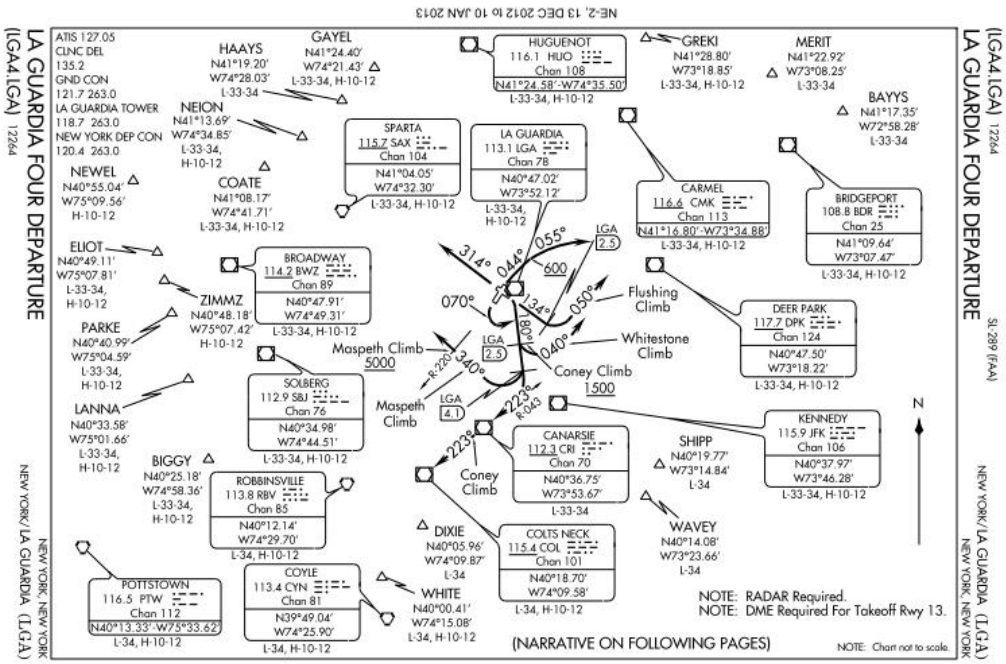
Figure 3. The Belmont airspace delegation [5]

3) Runway 13 Departures on the LaGuardia# (LGA#) DP:

Note that VORs are not technically part of the departure gates and only fixes should be considered when using the following table. For a complete list of fixes grouped by departure gate refer to the orange boxes on the Exit Direction Guide.

NOTE: When JFK is conducting overflow operations, LaGuardia shall be restricted to Flushing Climbs ONLY.

When KJFK is landing…	Climbs to use is…	For type…	Going to…
Multiple Runways	FLUSHING	All	All Gates
13L/R or 31L/R	FLUSHING	All	All Gates
ILS 22L/R	CONEY	Jets	South Gates
	MASPETH	Jets	West Gates, North Gates, East Gates
	WHITESTONE	Props	All Gates
Any Approach to 4L/R OR VOR 22L Approach	CONEY	Jets	South Gates
	MASPETH	Jets	West Gates, North Gates
	WHITESTONE	All	Props: All Gates Jets: East Gates



NE-2, 13 DEC 2012 to 10 JAN 2013

4) RNAV Departure Procedures:

Use the chart below to determine which RNAV DP's are valid for various LGA and JFK configurations. If a pilot is unable or unwilling to accept the RNAV DP below, assign the LGA# DP or a non-DP clearance

When LGA is Departing…	And JFK is Departing…	Use RNAV DP…	For exits…
13	Multiple Runways	TNNIS#	All Gates
	13L/R or 31L/R	TNNIS#	All Gates
	4L/R or 22L/R	NTHNS#	DIXIE, WHITE, WAVEY, SHIPP
		GLDMN#	All Others
22	4L/R or 22L/R	HOPEA#	DIXIE, WHITE, WAVEY, SHIPP
		JUTES#	All Others

Figure 4. Restriction of LGA climbs due to JFK configurations [5]

c. The most interesting and impactful interaction is when JFK lands ILS 13 which forces LGA to land runway 13, which in turn has impacts on EWR and TEB. In this situation, areas 15 and 19 are released to JFK from 4000 feet and below as indicated in Figures 2 and 6. LGA is forced to approach high and loop around to land on ILS 13, using TEB as localizer, as shown in Figure 5 below. To accomplish this, LGA is given the low altitudes of areas 33/34/35 from EWR (3000-2700 or 2000-1800 depending on EWR landing 22's or departing 4's). See Figure 6. According to the observations during the site visits, TEB is held when LGA is landing ILS 13 and then is given 15 minutes of each hour to flush its arrivals while LGA arrivals are held. Huge amounts of delay are incurred. Based on the site visit observations, landing 13's is the best configuration for JFK; however, it is not used often in IFR because it forces LGA to land 13, but would be used more often if this situation is mitigated.

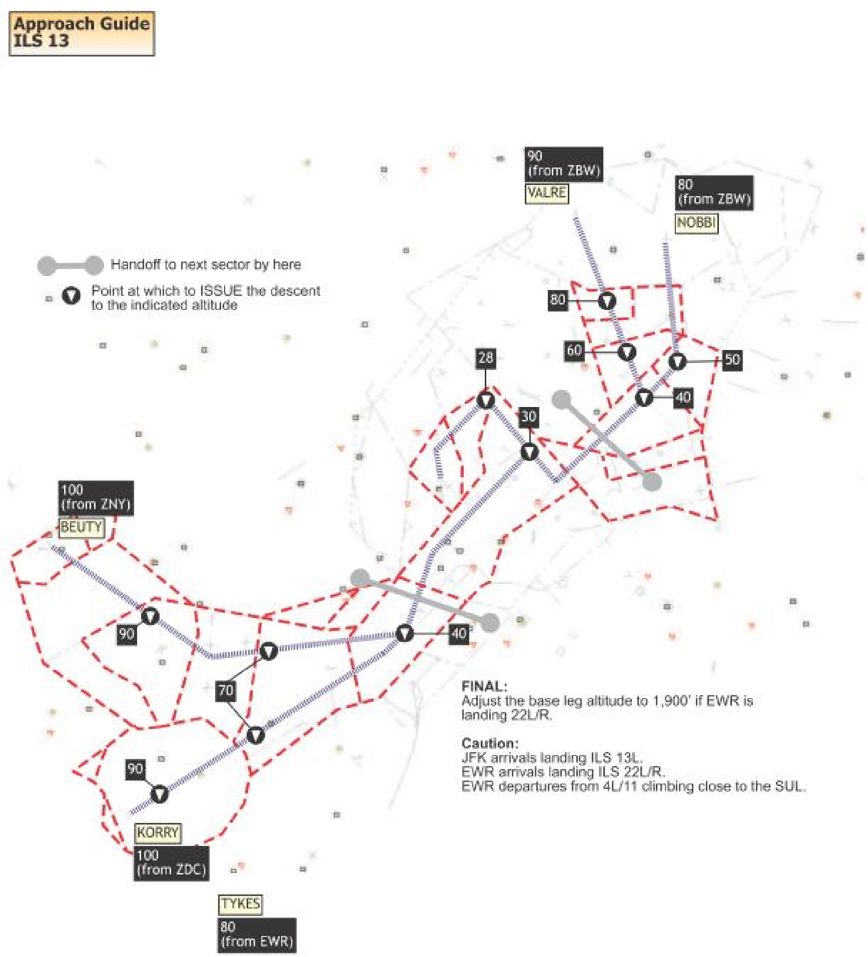


Figure 5. LGA ILS 13 approach [5]

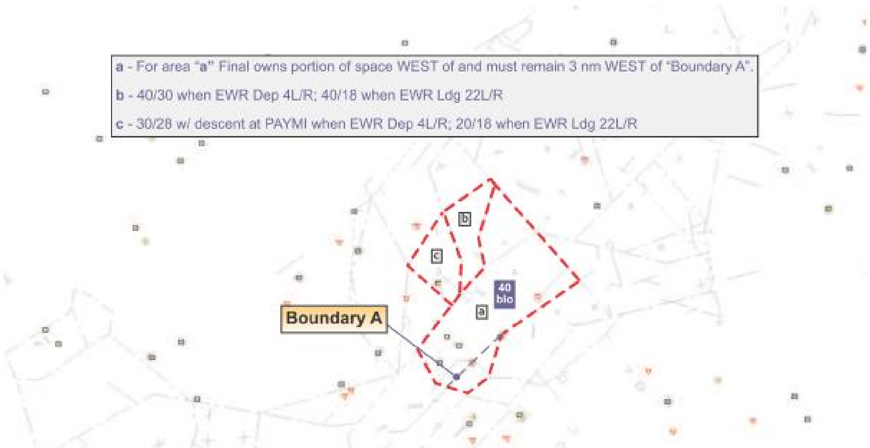


Figure 6. LGA-EWR interaction in LGA ILS 13 operation [5]

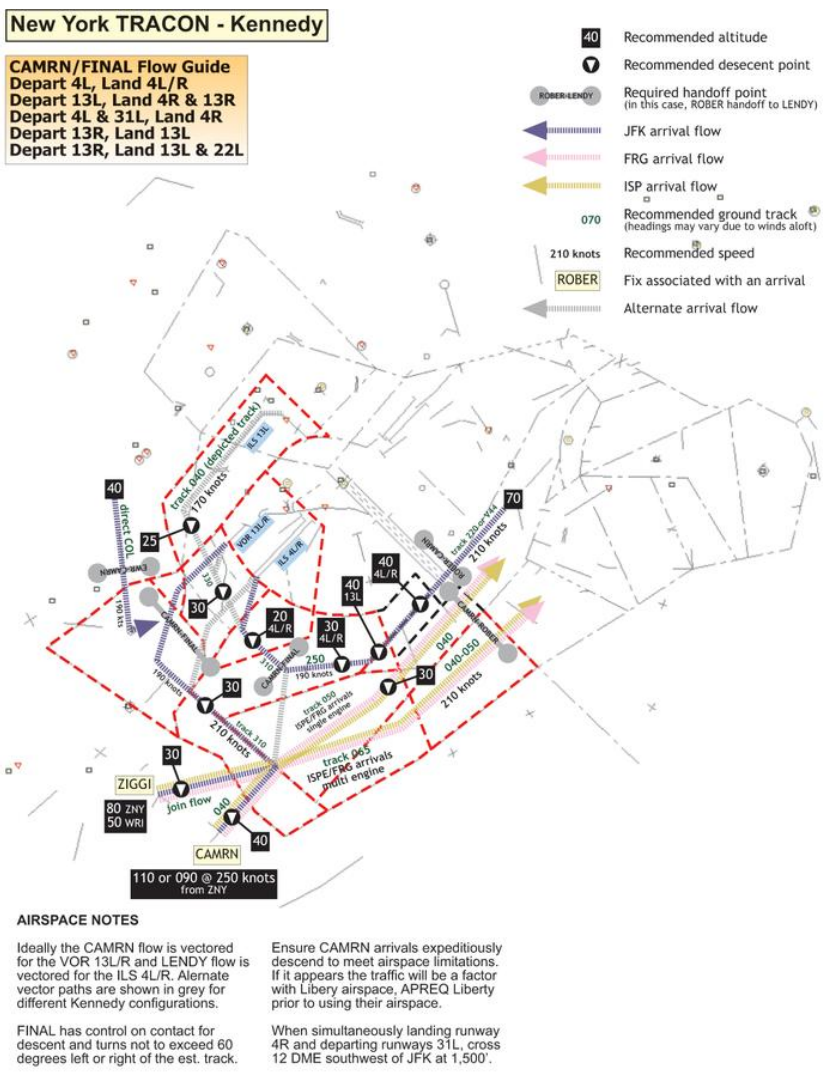


Figure 7. JFK approaches including ILS 13 approach [5]

[Potential application: Additional routes for LGA to land on runway 13, for example approaching from the west along with EWR, plus sharing of airspace with JFK and EWR with scheduling may mitigate this issue and enable better use of landing 13 and possibly 4 also at LGA, in IFR conditions in particular. This would also increase the use of landing runway 13L/R at JFK which is preferred. Scheduling is also needed to coordinate the TEB and the EWR flows (arrival or departure depending on the configuration) with the LGA arrivals on runway 13].

Generally, the interactions between the arrival and departure flows are similar between the different runway configurations except near the final approach. The interactions in the JFK ILS 13R/L, which forces LGA to land ILS 13, are the most interesting and challenging. Hence they are suggested as the N90 example case and most of the figures described below are shown in this configuration. The interactions presented also serve to highlight the generic interactions in case another case is selected

2. There are interactions between the departures and arrivals of the same airport and of adjacent airports, as the departures start below the arrivals and climb above the arrivals. Two examples are shown in Figures 8 and 9 in the EWR northeast and southwest flow directions, respectively, where the EWR arrivals in the southern and northern flows are maintained at 6000 feet to avoid the westbound departures at 7000 feet. Westbound departures are also shown in these figures, which indicate that LGA and JFK westbound departures may also be impacted by this intersection since they are merged. Figure 10 shows the merging between the JFK westbound departures and the EWR eastbound departures with the corresponding LGA departures.

   [Potential application: This coordination is currently achieved through airspace delegation; while sharing of airspace combined with scheduling may help avoid some of the resulting level offs and delays.]

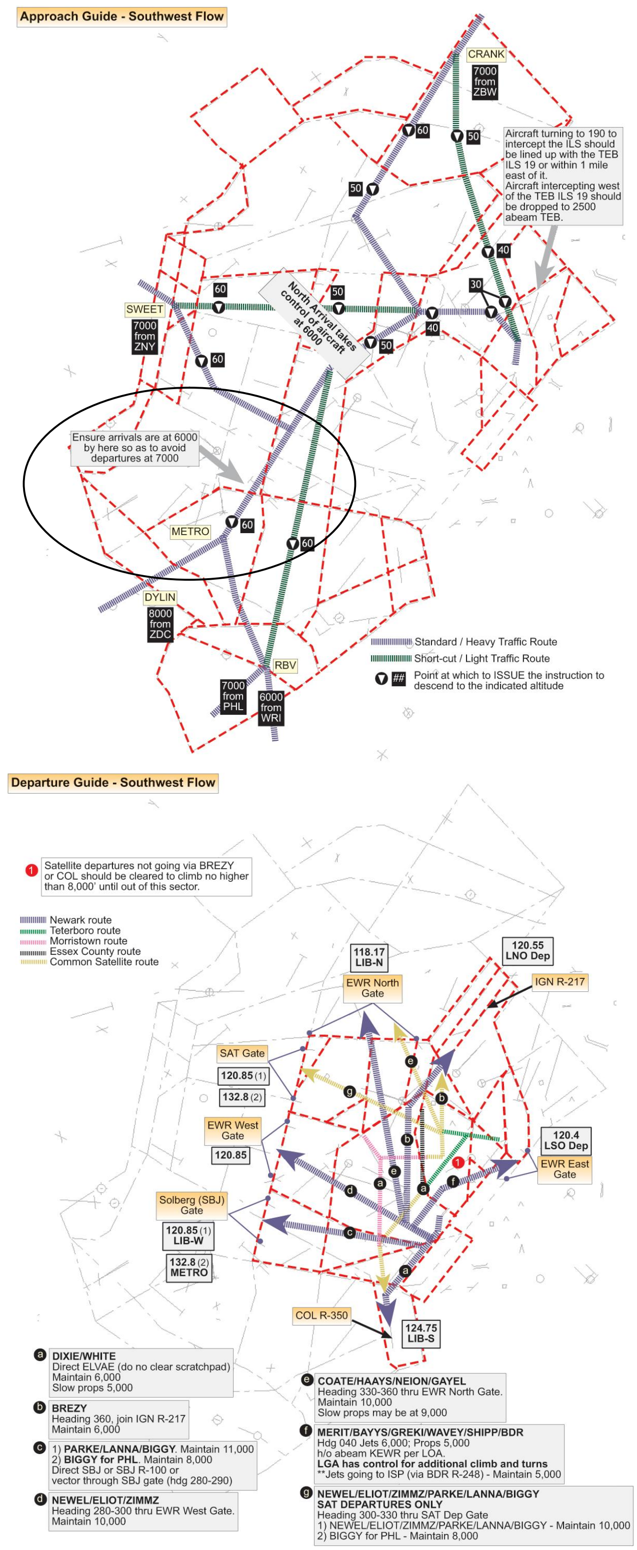


Figure 8. Intersection between EWR southern arrivals and westbound departures

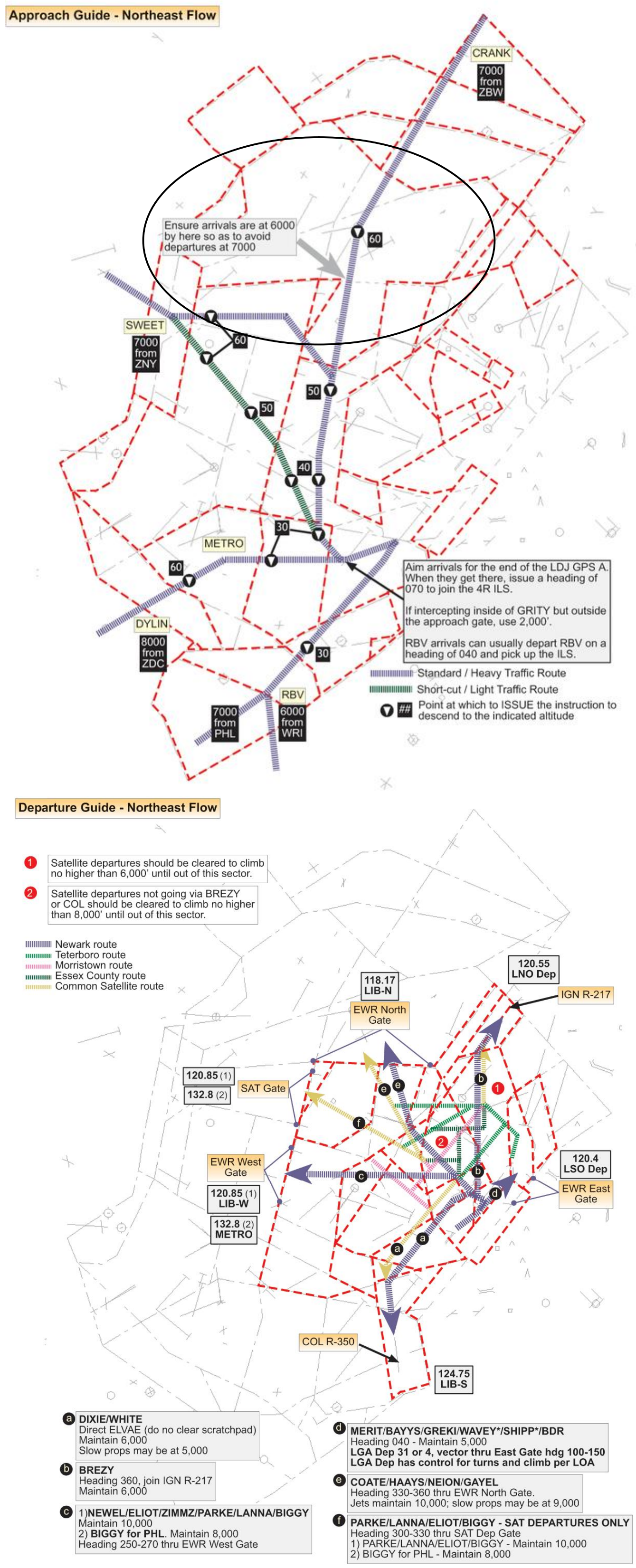


Figure 9. Intersection between EWR northern arrivals and westbound departures

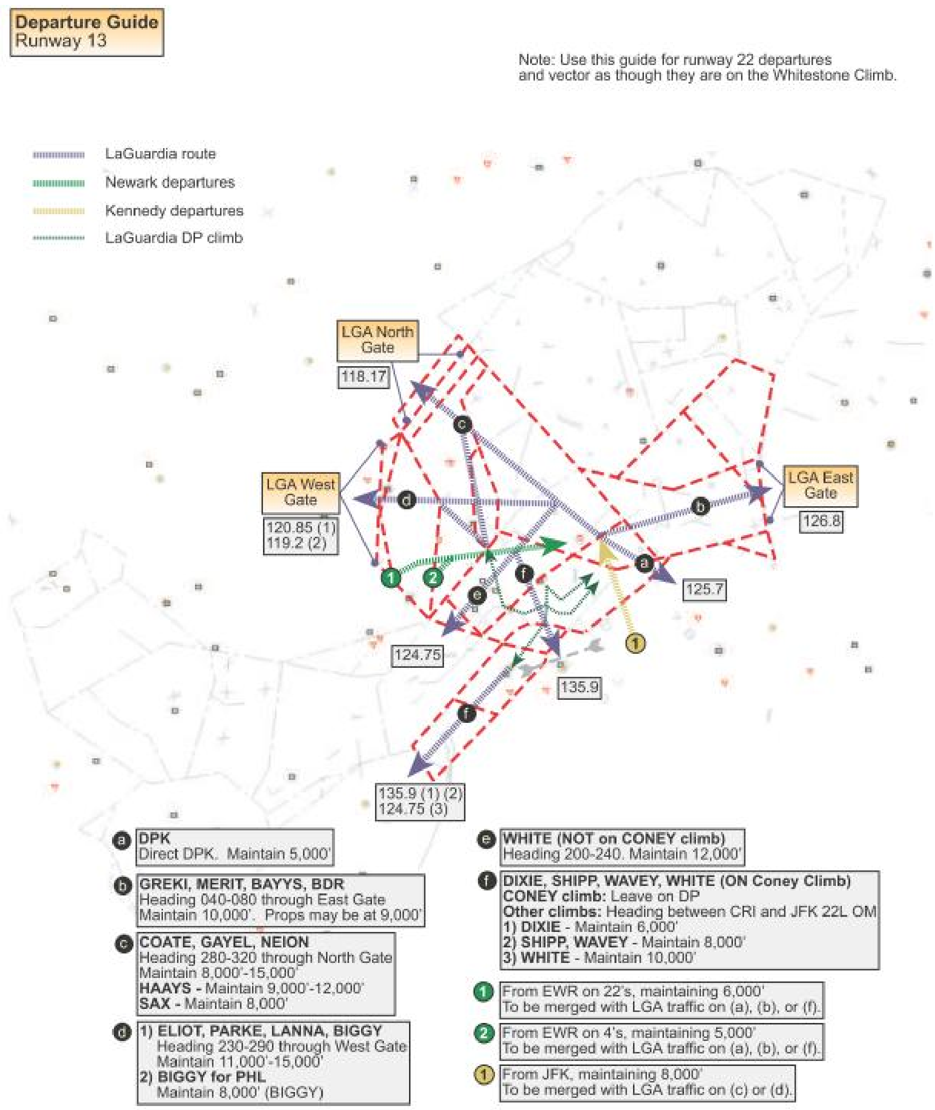


Figure 10. Westbound departures of JFK and eastbound departures of EWR merge with the corrsesponding LGA departure flow.

3. LGA arrivals approach above the EWR arrivals as can be seen from Figure 5 (LGA) and Figure 8 and 9 (EWR). According to the observations this creates high workload in managing the LGA arrivals, which often experience opposing wind fields as they transition through 7000 feet. Ideally, according to the SME input it is desired to bring all traffic to similar altitudes with comparable speeds for more manageable merging. Additionally, the EWR southbound departures, as well as the EWR arrivals from the south, are maintained at 6000 feet below the LGA arrivals from the south at 7000 feet. This may also lead to level offs.

[Potential application: Sharing of airspace and scheduling may mitigate this issue by allowing the LGA arrivals to approach along lower altitude profiles when beneficial].

4. JFK arrivals approach from the west high above the other airports and loop around to descend to the runways as shown in Figure 11.

   [Potential application: Sharing airspace may mitigate some of this issue allowing JFK to approach at lower altitudes and reduce the need for looping]

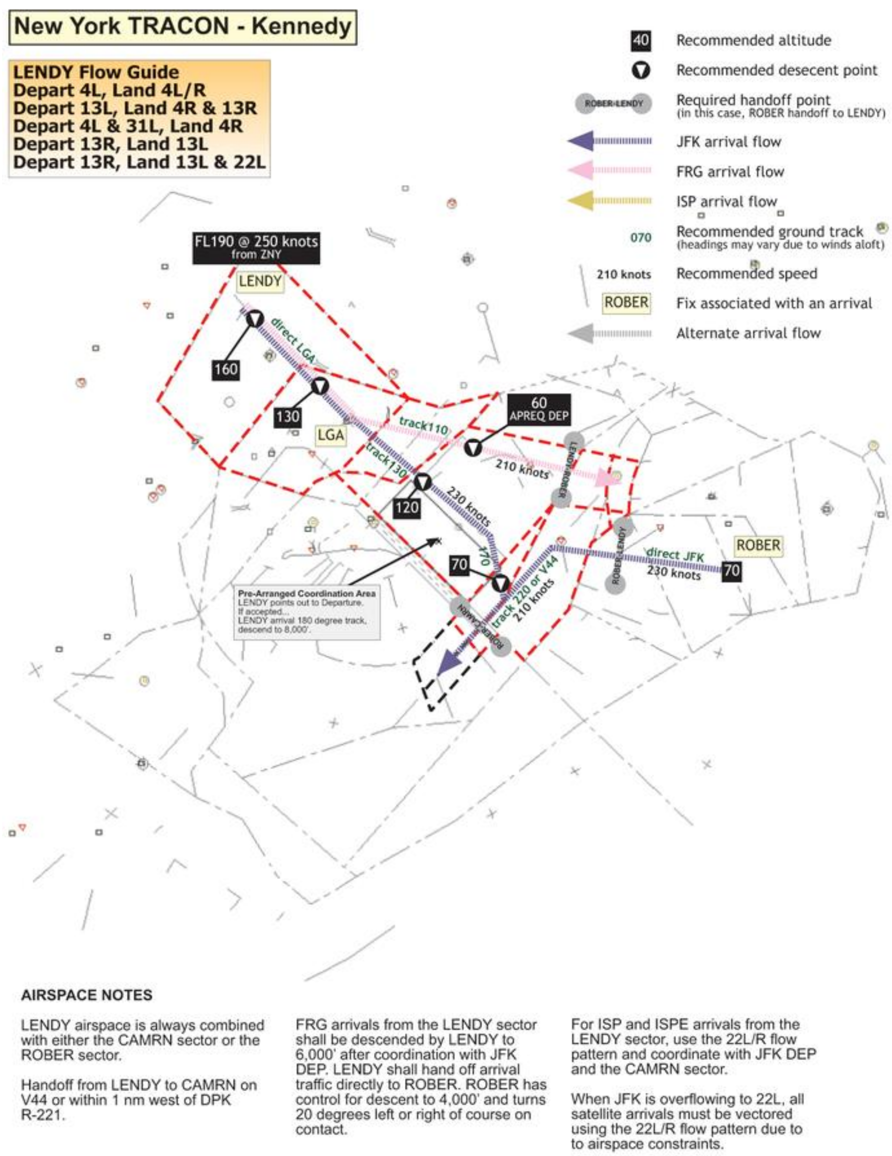


Figure 11. JFK approach from the west

Runway interactions

Diagrams of the four major airports JFK, EWR, LGA and TEB are shown in Figure 12. The runway interaction between arrivals and departures is highest at LGA among the major N90 airports. LGA has two crossing runways and therefore arrivals and departures are dependent in all their runway configurations. TEB also has two crossing runways and handles general aviation. EWR has two closely spaced runways, one used for arrivals and one for departures, which couples the operations. EWR is also able to offload operations to the crossing runway 11/29, which creates a challenge of the runway 11/29 operations shooting the gaps between the arrivals and departures on the primary runways. JFK is the least constrained airport with many runway configurations. In most configurations JFK is able to depart aircraft independently of the arrivals. JFK also has a schedule that alternates between arrival and departure pushes, which reduces the interaction between them. According to the observations during the site visits, JFK operates as either an arrival or a departure airport, while LGA attempts to run one departure for one arrival almost all the time. For these reasons, it is suggested that LGA serves as the primary case for the analysis of runway interactions, with EWR and JFK as complementary. The case suggested for this analysis where JFK lands ILS 13 and LGA is forced to land 13 couples all three airports in addition to TEB.

According to the observations during the site visits, LGA attempts to perform one-to-one arrival and departure operations. The TRACON provides pre-coordinated gaps to enable this tradeoff. However, often gaps are partial and allow only a fraction of a departure which is a waste of capacity. When departure queues form, there is a desire to depart multiple departures between two arrivals. Therefore, integrated scheduling between arrival and departure runway operations can produce significant benefits. This was also demonstrated in a recent HITL study at NASA for the concept Departure Sensitive Arrival Scheduling (DSAS).

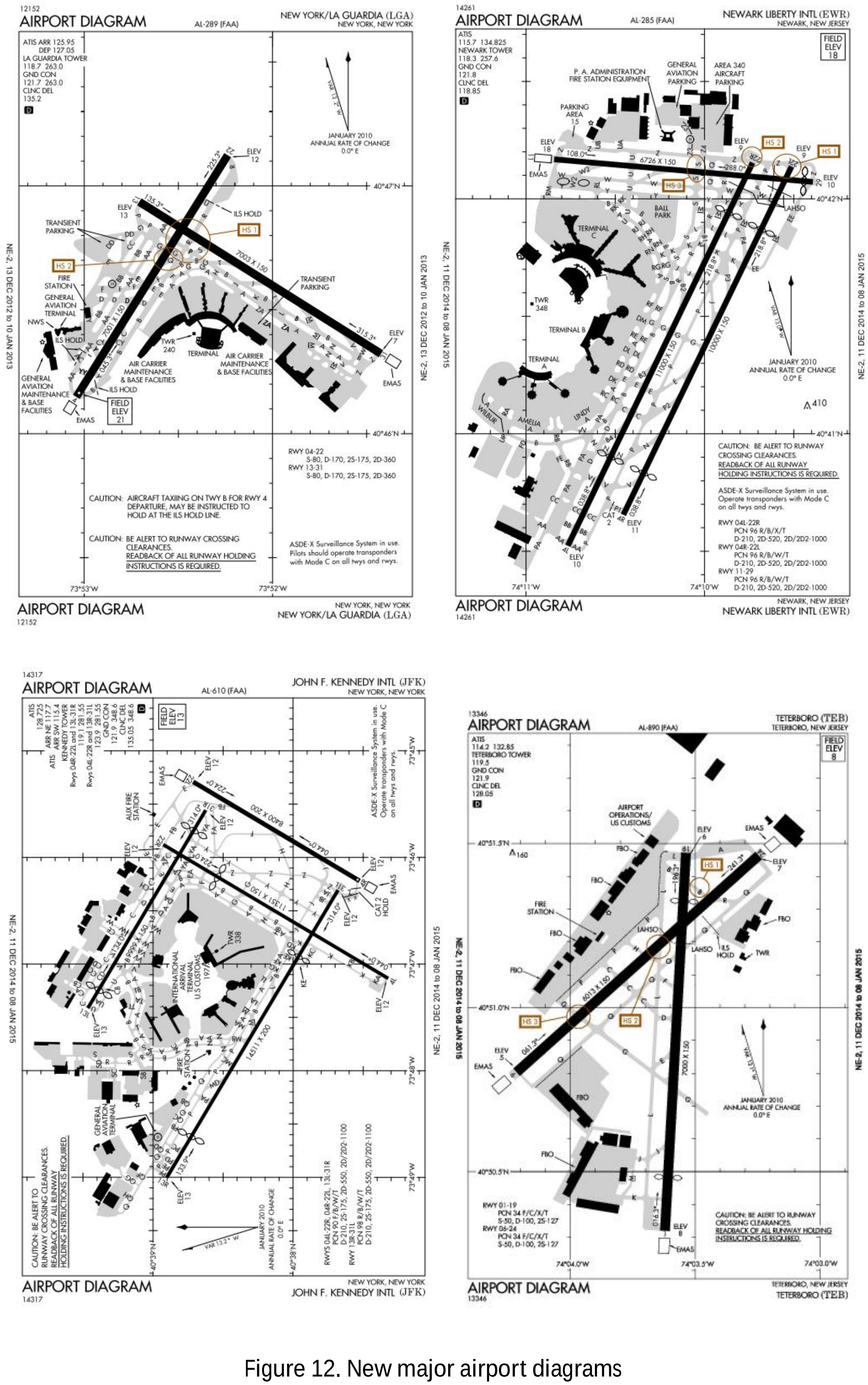


Figure 12. New major airport diagrams

According to the observations, LGA runs single departure heading from their runways, and sometimes asks for two headings off runway four. Guidelines for the departure headings are given in the SOP and shown in the excerpt below in Figure 13.

4) LaGuardia 4 SID Departures

__Runway 31__
For Runway 31, issue the appropriate initial heading from the table below. These headings are not shown on the LGA4 SID.

Exit	Heading
East Gates	010
All others	340

__Runway 13__
Re-state the climb as part of the takeoff clearance. Pilots tend to forget. *"CALLSIGN, fly the NAME Climb, wind ### at ##, Runway 13 cleared for takeoff"*

5) RNAV SID Departures

__Runway 13 & 22__
Re-state the SID as part of the takeoff clearance. *"CALLSIGN, Climb via the XXX Departure, wind ### at ##, Runway 13 (or 22) cleared for takeoff"*

6) Non-DP Departures: Departures ***NOT*** on a SID, issue one of the following headings as part of the takeoff clearance:

Runway	Heading
4	Fly heading 055
13	IF climb would be **Flushing** or **Whitestone**: 050 IF climb would be **Coney**: 220 IF climb would be **Maspeth**, you will "vector" the Departure as if on the Maspeth: a) Issue an initial heading of 180 as part of the takeoff clearance b) When you see the departure reach 2500' – 2800', issue a RIGHT turn to heading 340 c) Once you **observe** the departure is turning properly, issue the instruction to switch to the appropriate departure frequency or Unicom. ***The Maspeth Climb calls for flying 180 until reaching 3000', the instruction to turn to 340 at 2500' – 2800' will be executed at ~3000' once the pilot reads it back and actually turns the plane. This prevents the NUMEROUS conflicts with JFK that arise routinely***
22	Turn Left Heading 070
31	010 for East Gates 340 for all other exits

Figure 13. Departure headings at LGA

Taxi and ramp interactions

LGA and JFK provide an interesting case for comparing the impact of taxi constraints on arrival departure interactions.

1. JFK has a lot of taxiways and multiple route options for sequencing and holding departures. LGA has less taxi route options.

2. JFK performs departure metering to maintain the runway queues below 12 aircraft. JFK has a lot of gate and ramp space to perform metering, its schedule is either arrivals or departures with minimal overlap, and the turnaround time is high, all factors that enable departure metering. On the other hand, LGA does not have sufficient gates to hold aircraft and instead parks delayed departures on taxiways (for example to the west side of runway 4/22), its schedule has balanced arrival and departure loads, and its turnaround time is small, all factors that limit the ability to perform departure metering. Hence, at LGA integrated scheduling of arrivals and departures may need a higher level of coupling. For example, a missed departure slot at LGA causes departure queues that remain for the full day cycle.

LGA SOP contains instructions for default taxi routes, crossing runways and for sequencing of departures. For example departures are to be sequenced by alternating gate, then by alternating exits within a gate, then by aircraft type (largest to smallest).

The ATL case

The main sources of the analysis of the ATL case are observations conducted during site visits to the Tower and the TRACON, SOP's in October 2014 and documentations obtained during the visits, and the OAPM analysis available online [2]. Further SME input will be obtained to confirm or adjust this analysis.

Interactions between arrivals and departures are highlighted under the following categories:

a. Airspace interactions
b. Runway interactions
c. Taxi and ramp interactions

Airspace interactions

ATL operates in one of two main directions based on the runway layout: East and West. The airspace is correspondingly delegated to arrivals and departures as shown in Figures 14 and 15 for the two flows respectively, which are almost mirror images of one another. As can be seen from the figures, ATL is designed as four corner posts, with arrivals approaching from the four corners and departures climbing through the sides. Aircraft approaching from the longer side (from the northeast and southeast in east flow and from the northwest and southwest in the west flow) approach at or above 10000 feet until the downwind. From the opposite shorter sides they approach at or above 9000 feet. The downwind is performed at 7000 feet. The base legs from opposite sides are 1000 feet apart to avoid nose-to-nose conflicts. Departures stay below the arrivals on the eastern side in the east flow and on the western side in the west flow, climbing only to 9000 feet. As they loop to the other side they climb above the arrivals maintaining at or above 11000 feet depending on the airspace region. This process often leads to the leveling off of departures and arrivals to maintain their altitude limits as designed by the airspace delegation.

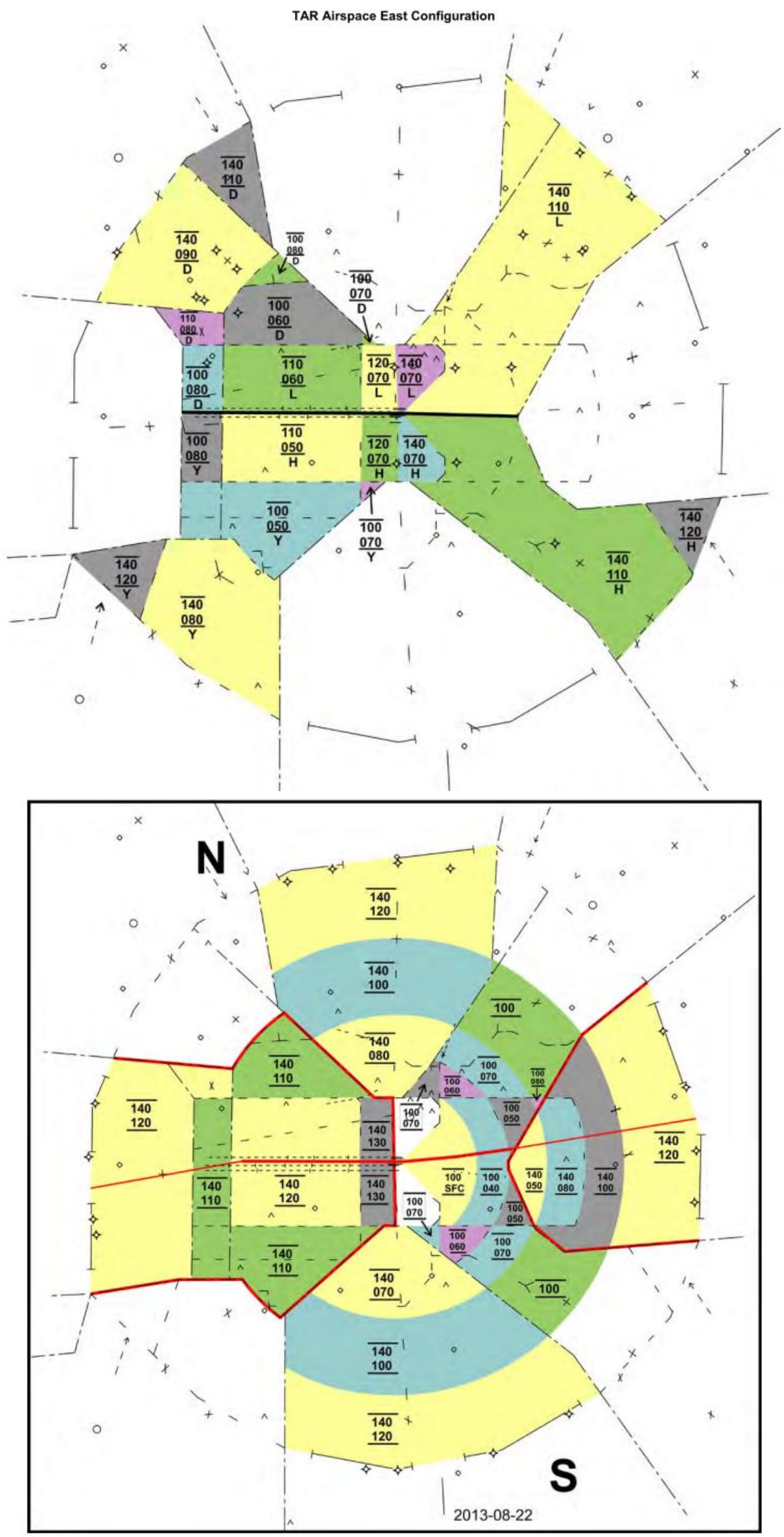


Figure 14. ATL airspace delegation in the east flow

TAR Airspace West Configuration

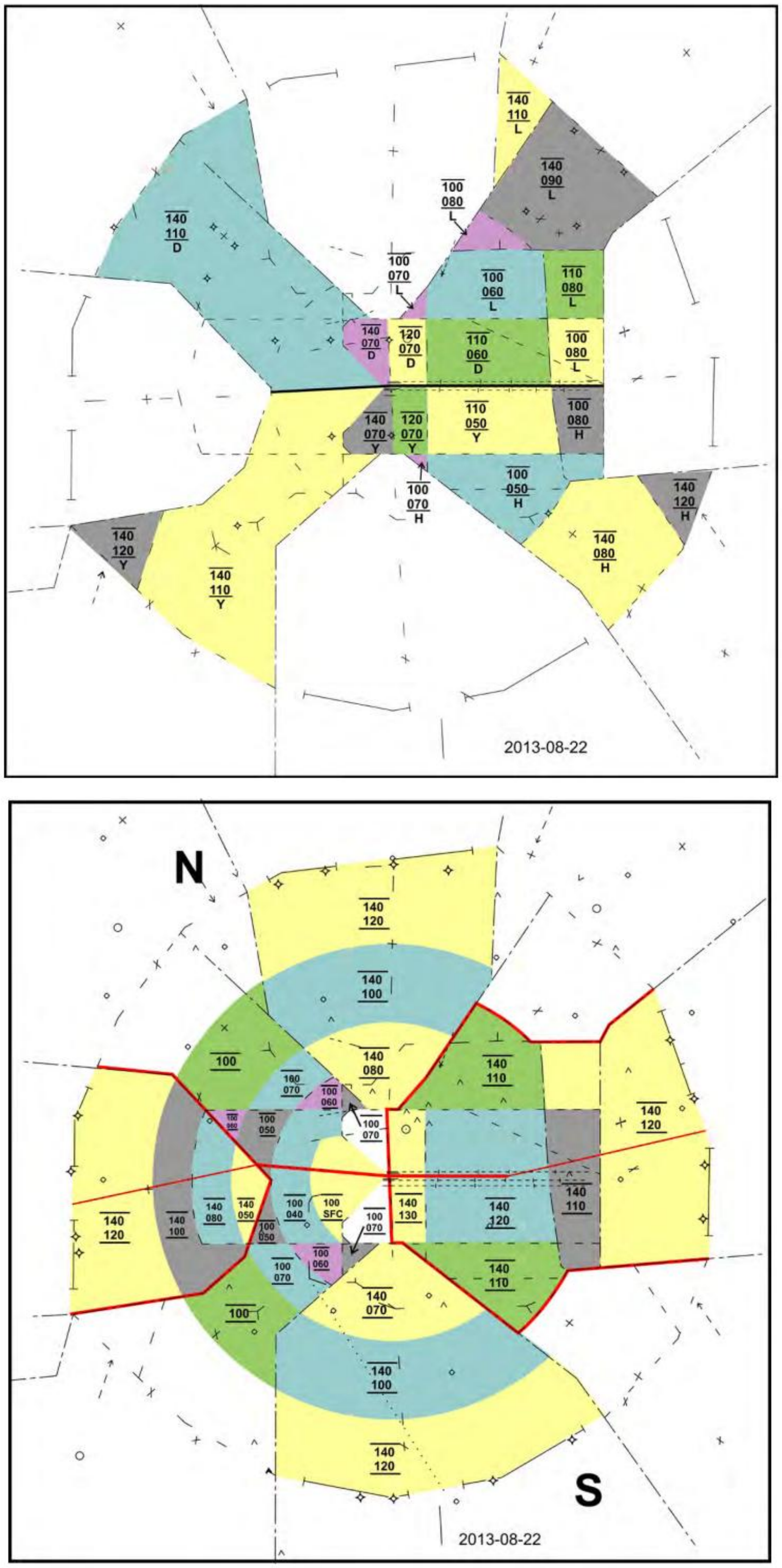


Figure 15. ATL airspace delegation in the west flow

The instructions to the departure controllers in the SOP are to attempt to enable the aircraft continuous climb to the extent possible: “Transfer communication to an adjacent sector as soon as possible to enable the aircraft to continue an uninterrupted climb”. To help accomplish this, ATL has pre-arranged coordination areas (see Figure 16) in which the departures can penetrate the arrival airspace under the control of the departure radar controller, who is responsible to maintain separation from the arrivals. The arrival controller points out traffic to the departure controller, obtains altitude read outs from the aircraft under the departure control, and can terminate the pre-arranged coordination as needed. This procedure indicates significant interaction between the arrival and departure flows. Typically, the departure controller attempts to maneuver the departures in the arrival airspace if needed to maintain continuous climb and to reduce the travel distance to the destination through short cuts. During the site visit, the departure controller in the northwest corner was observed coordinating with the arrival controller to enable continuous climb as an arrival and a departure converged on an intersection point. This behavior was mentioned as a typical interaction between arrivals and departures.

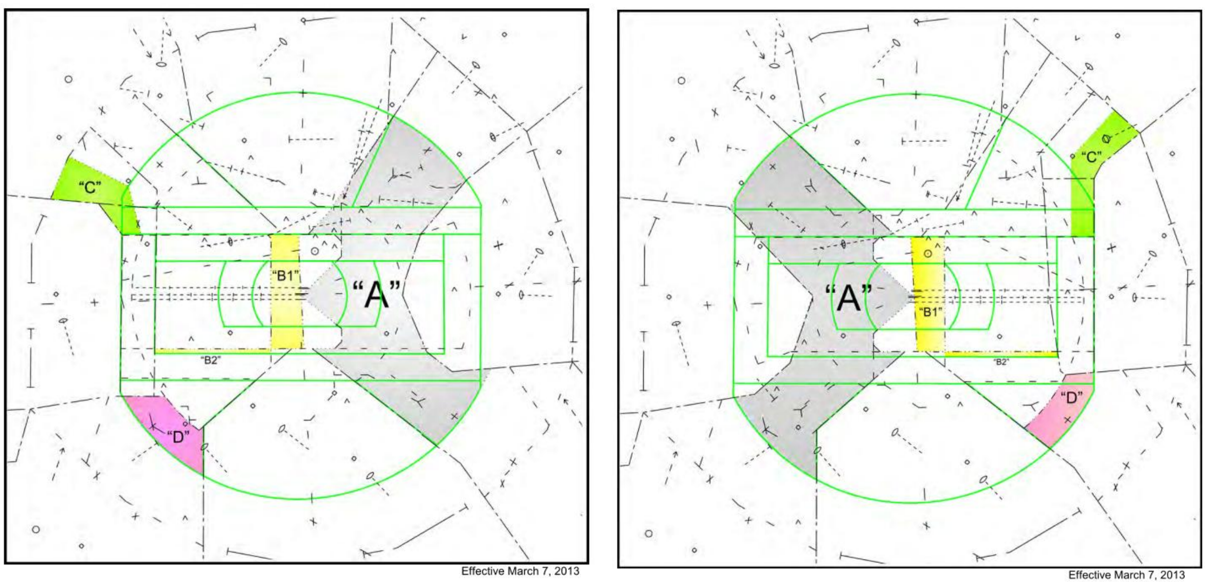


Figure 16. Pre-arranged coordination areas in ATL

Figure 17 below shows one day of ATL arrival and departure traffic using PDARS data (obtained from the site visit). The arrival and departure flows are segregated clearly where the arrivals approach from the four corners and the departures exit through the sides of the terminal airspace. After exiting the terminal, a significant number of departures can be seen leaving their original stream (which is perpendicular to the terminal side) and heading towards routes that are aligned with the arrival approach streams. This is an indication of the detour that the corner post flow structure imposes on some of the flights, whose direct route to their destination would pass through a corner of the terminal airspace rather than one of the sides (and vice versa for the arrivals). Such flights would benefit from transition points that are more distributed along the perimeter of the terminal area. The pre-arranged coordination discussed above is a means to enable some flights to conduct a more direct route and a more continuous climb when the arrival flow allows. The OAPM study, realizing this issue has introduced a larger number of transition points between the terminal and the en route airspace [2]. However, the OAPM recommendations maintained the segregation of the arrivals and departures using the corner posts structure.

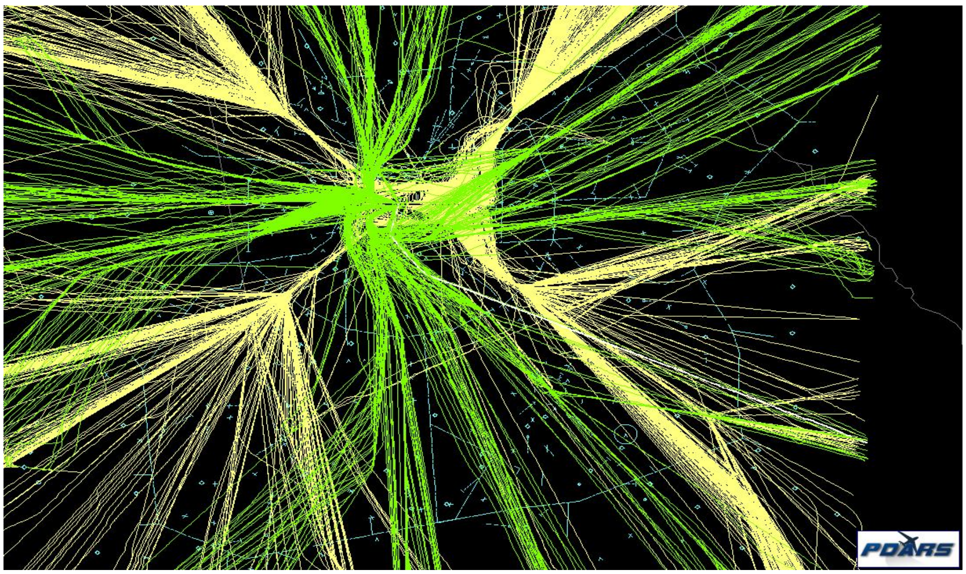


Figure 17. One day of ATL arrival and departure traffic [7]

[Potential application: The pre-arranged coordination between the arrival and departure flows may be supported by scheduling of arrivals and departures at pre-designed intersection points along multiple route options connecting the arrival and departures standard routes.]

This observation is also an indication that it is important to assess the impact of the planning of the traffic within the terminal airspace on the remainder of the flight outside the terminal airspace. It is important to consider the airport/terminal or metroplex problem as an integral part of the NAS as a whole and not in isolation.

ATL offers a rich set of designed RNAV routes: RNAV routes connect the arrival fixes with all of the runways and off the ground (OTG) RNAV routes offer connectivity between all the runways and all departure exit fixes as seen in Figures 18 and 19, respectively. This may be an advantage for using ATL for analysis with the added flexibility of these routes. Additional route segments may be added for example to interconnect the arrival and departure route structures for the proposed solutions. It is not clear from the reviewed documentation if similar routes are available at other airports (Additional SME input will be obtained).

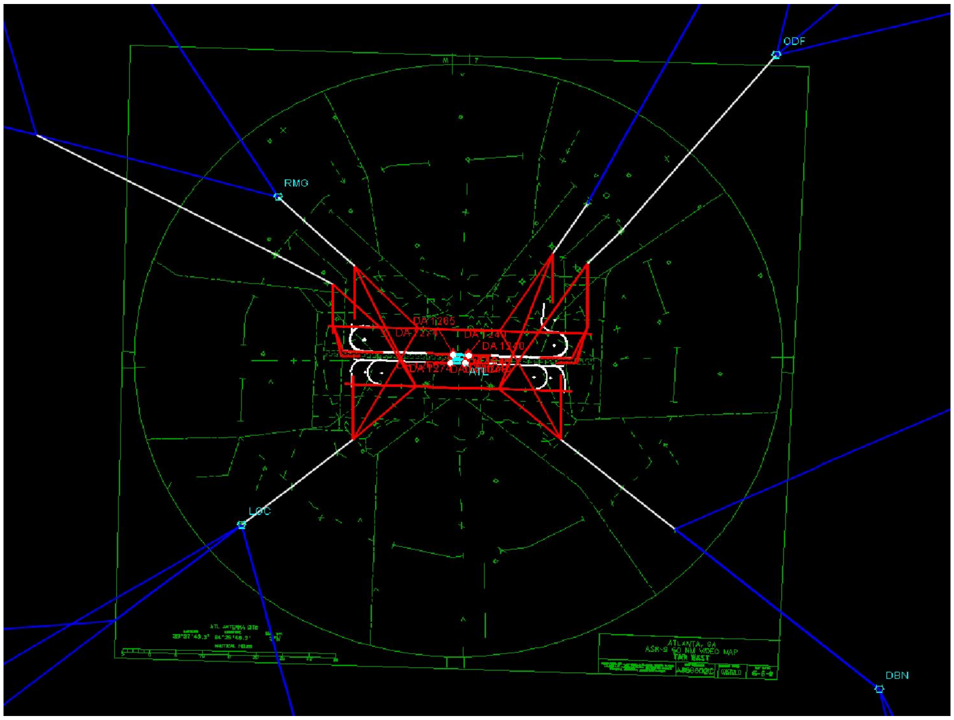


Figure 18. ATL RNAV approach routes connecting STARs to runways[7]

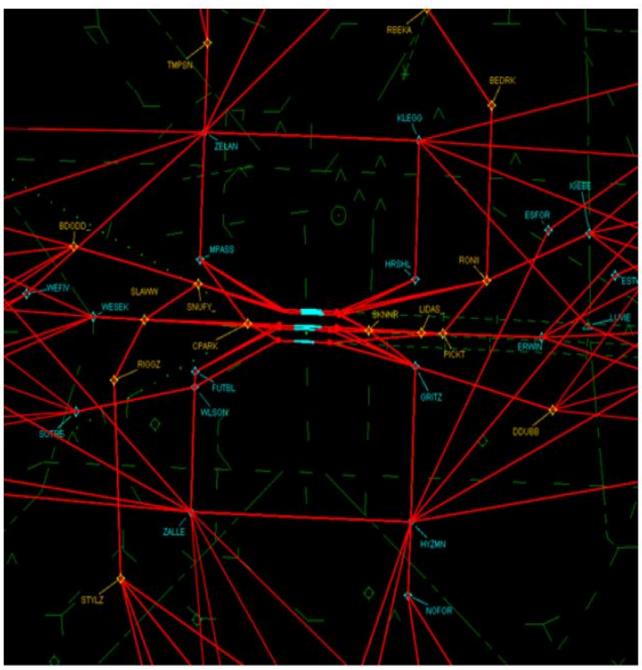


Figure 19. ATL off-the-ground RNAV routes connecting runways to departure fixes [7]

The Zelan RNP SID route shown in Figure 20 (obtained from the site visits) is a new concept that connects runway 27R with the ZELAN fix to the north of the airport. This route will allow departures that currently turn left to turn right and cross into the north complex with high precision. This will enable the departures from runway 27R heading to the northeast, for example, to avoid a long loop where they currently turn left and loop around to the east side gates. This example indicates the flexibility that is desired by enabling additional routes and less segregation of arrival and departure flows. Such routes add the opportunity for airspace sharing and scheduling.

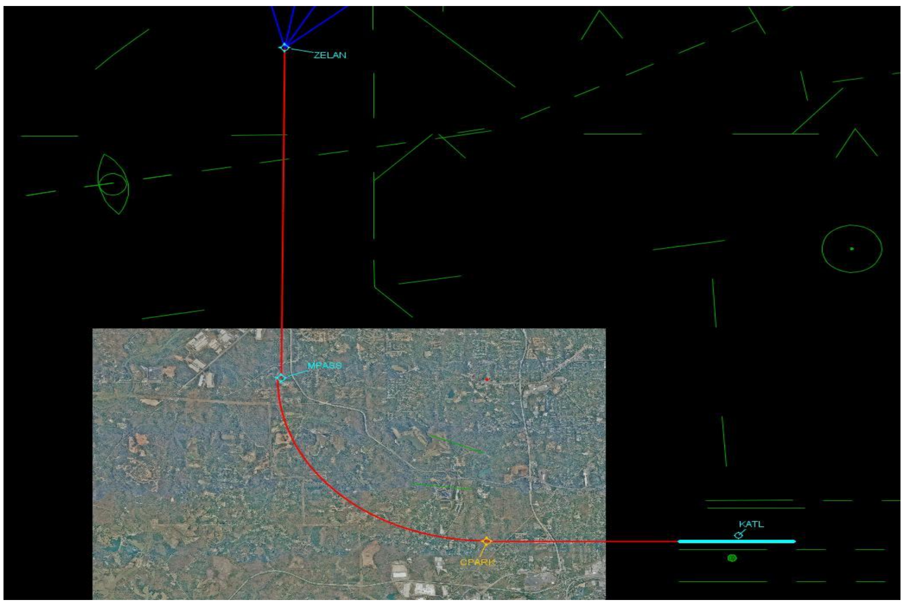


Figure 20. RNP departure route at ATL enabling crossing across runway complexes [7]

Runway interactions

ATL has five runways as shown in Figure 21: Runways 8L/26R, 8R/26L, 9L/27R, 9R/27L, and 10/28. The interdependence between these runways is explained in Figure 20 which is an excerpt from the SOP. Typically arrivals are independent on the three runways 8L/26R, 9R/27L and 10/28 with precision runway monitoring (PRM). If PRM is not available, simultaneous ILS approaches are conducted to 8L/26R, 9L/27R (with side stepping to 9R/27L) and 10/28. Departures and arrivals in the same complex have to be coordinated as a single runway operation.

ATL has the ability to use either two or three runways for arrivals or departures in each direction. This enables adjusting the capacity to match the demand. Typically runway 10/28 is the one that is shifted between arrival and departure use.

[Potential application: This enables for example, scheduling either arrivals or departures on a runway exclusively for a period of time to match the demand.]

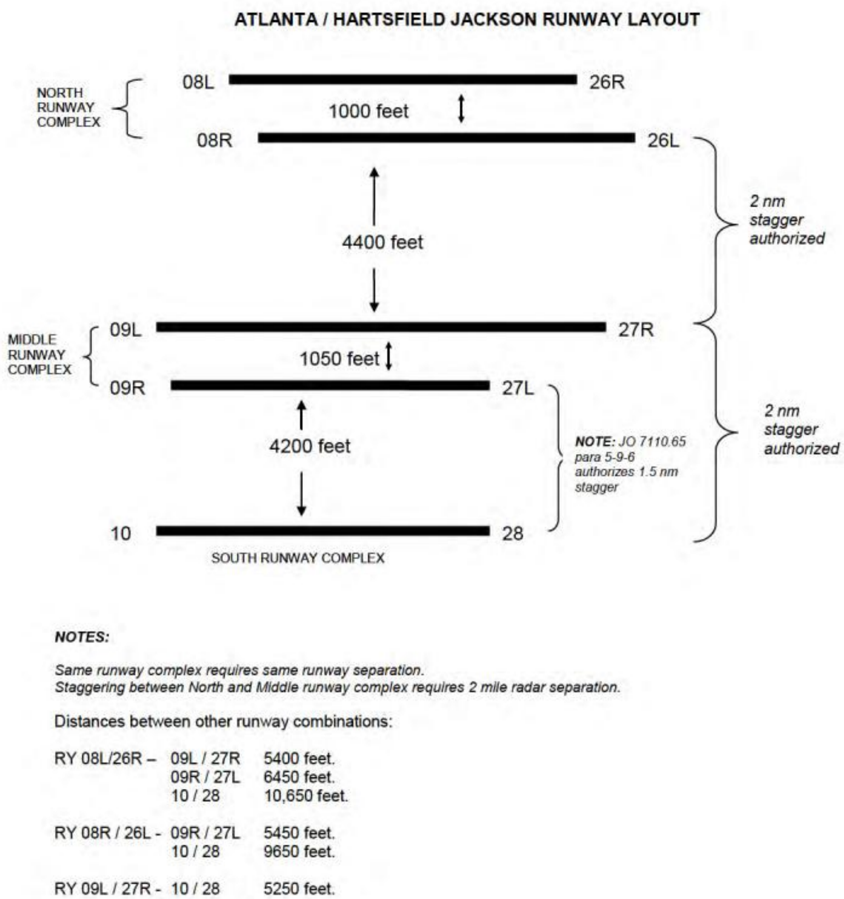


Figure 21. Runway interdependence at ATL [6]

Departures have to maintain the RNAV/noise heading until five miles from the departure end of the runway or 5000 feet is reached.

Runway assignment may be changed by the approach controllers even on the downwind or base legs. This behavior was also observed in the site visit to the TRACON where the TMC at the TRACON was making decisions to assign flights to runways based on their gate location (user concerns) in addition to load balancing.

The runways and departure exits are associated in a process called a departure split. Adjacent departure fixes cannot be split between two different runways.

Taxi and ramp interactions

Ground control is divided into three control positions: north (controls taxiways above a centerline though the midfield terminals), center (controls taxiways between the centerline and runway 9R/27L), and south (responsible for traffic between runway 9R/27L and runway 10/28). The south position is typically combined with center (or with a local controller). Two ground meter positions (north and south) also typically combine to ground control (north and center respectively). The ground metering position provides the flight progress strips to the ground controller in the order that they called for taxi and coordinates with the TMC or CC (cab coordinator) when an aircraft requires a release.

The SOP contains detailed instructions about the nominal taxi routes between the runways, the nominal runway assignment, and sequencing instructions. Based on the site observations, ATL has ample space to hold taxi queues and can absorb a large amount of departure delay, as high as 45 minutes, before having to take action to favor departures.

As shown in Figure 22 below, a loop (taxiway V) is available to taxi around runway 8R/26L to avoid crossing the departure runway by the arrivals on 8L/26R. The figure shows the taxi process in the east flow while a symmetric process is conducted in the west flow. This loop operation results in favoring of the north side over the southern side in assigning flights to the runways. A similar process is conducted on the south side by lining up departures at the M intersection of runway 9L and simultaneously taxiing aircraft to cross the runway at taxiway P. Arrivals on 9R and 10 cross runway 9L at Papa. If the traffic on the departure runways (8R or 9L) is light, the controllers may instruct the arrivals to cross the departure runway if it results in a better taxi in time depending on the location of the ramp.

[Potential application: This creates a multi-route option for the taxi route decision, which has implication on the runway scheduling because one option crosses the runway while the other does not.]

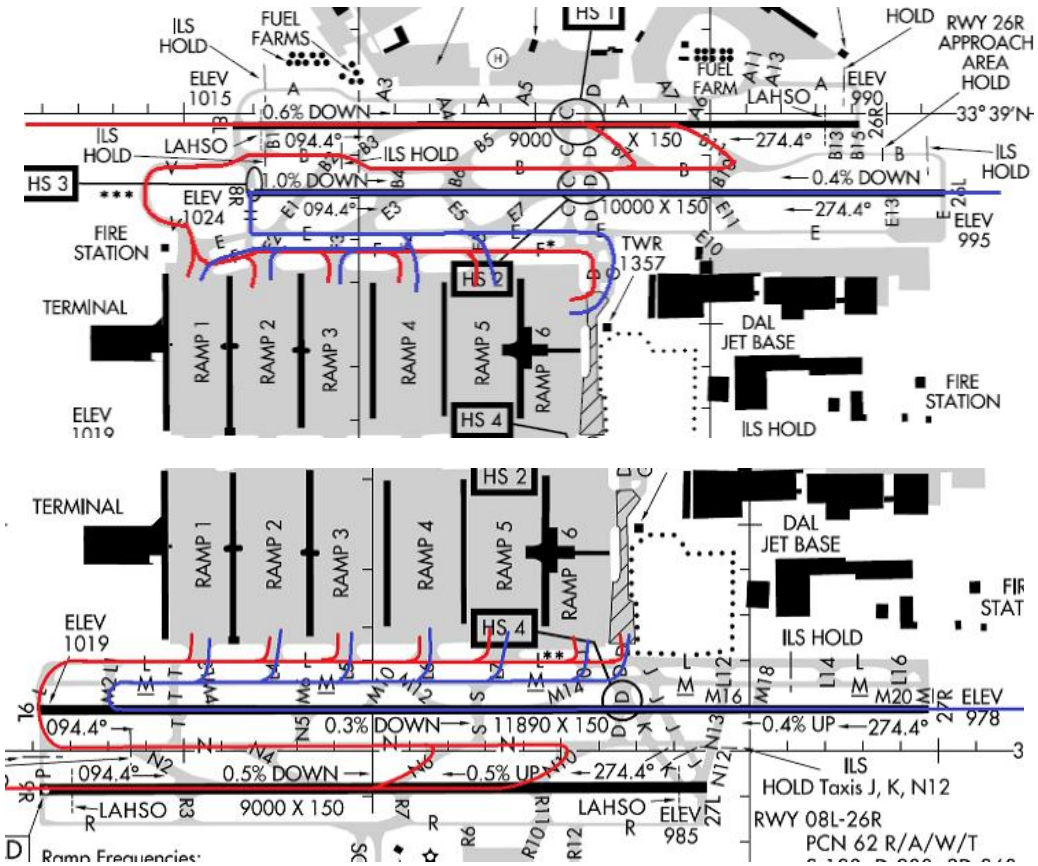


Figure 22. Taxi around and across runway at ATL [6]

Mostly, the ramp areas are separated from the movement area and aircraft are introduced into the movement area at well defined taxi spots as shown in Figure 22. There is some blockage of the taxi operation by pushbacks as indicated in the SOP: "Ramp 5 / 6 tower will advise the cab coordinator via the ring down line when an aircraft (B757 or larger) that will depart the south runways requests to pushback across the zipper line between Ramp 5N and Taxiway F. The CC will coordinate with GC-N that the aircraft will be pushing back onto taxiway F." The OAPM study also identified an issue where aircraft in the ramp area are unable to turn to the opposite direction within the ramp. Therefore, they use the movement area in order to turn to the other direction.

The CLT case

The main sources of the analysis of the CLT case are the tower and TRACON SOPs available online dated 2011 [6], and the OAPM analysis [3]. SME input will be obtained to confirm or adjust this analysis.

Interactions between arrivals and departures are highlighted under the following categories:

a. Airspace interactions
b. Runway interactions
c. Taxi and ramp interactions

Airspace interactions

CLT operates in one of two main directions based on the runway layout: South or North. The airspace is correspondingly delegated to arrivals and departures as shown in Figures 23 and 24 and Figures 25 and 26 (excerpts from the SOP) for the South and North flows respectively, which are almost mirror images of one another.

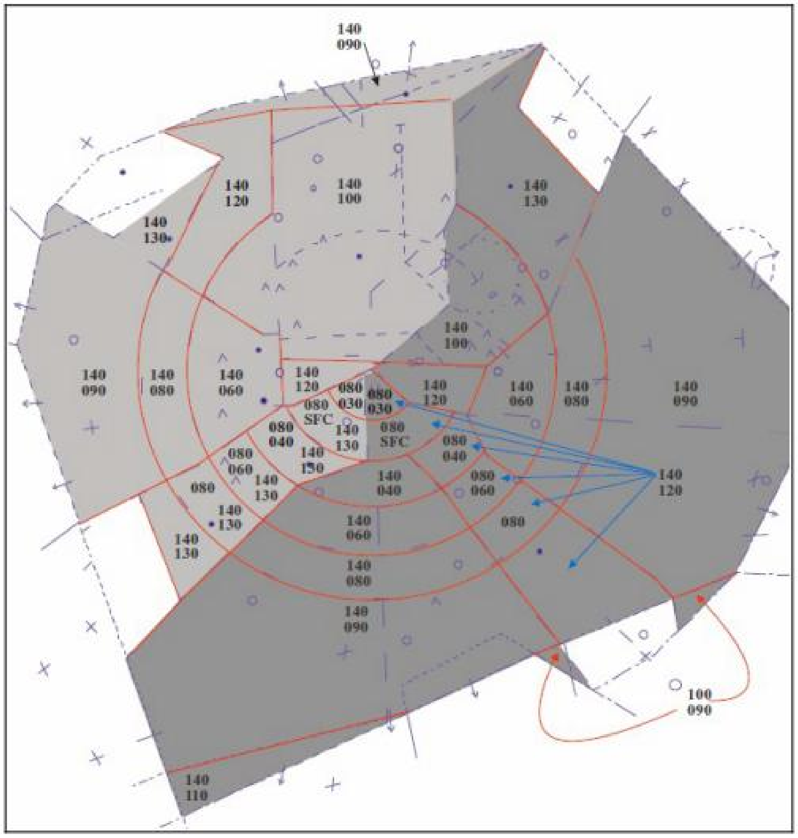
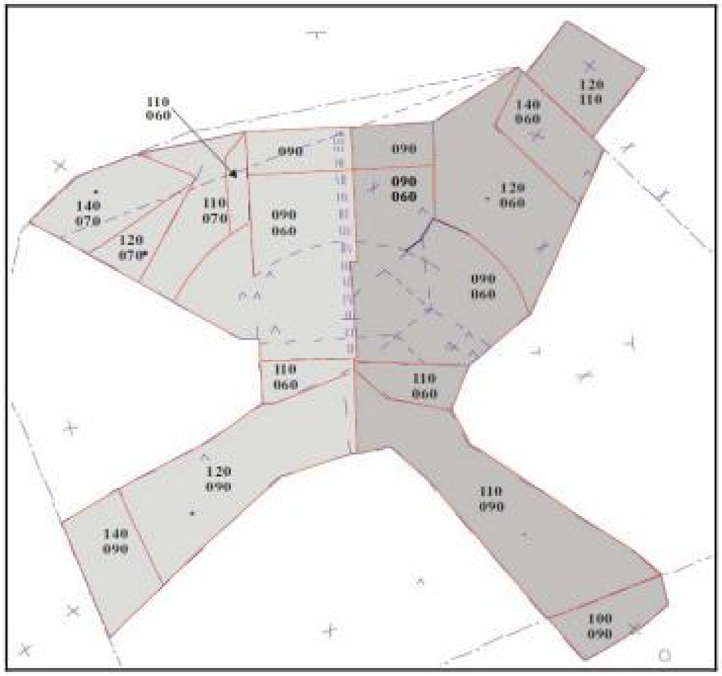


Figure 23. Airspace delegation for departures in the south direction at CLT [6]

ARRIVAL RADAR EAST/WEST AIRSPACE (SOUTH OPERATION) RUNWAY 23 INACTIVE



ARRIVAL RADAR EAST/WEST AIRSPACE (SOUTH OPERATION) RUNWAY 23 ACTIVE

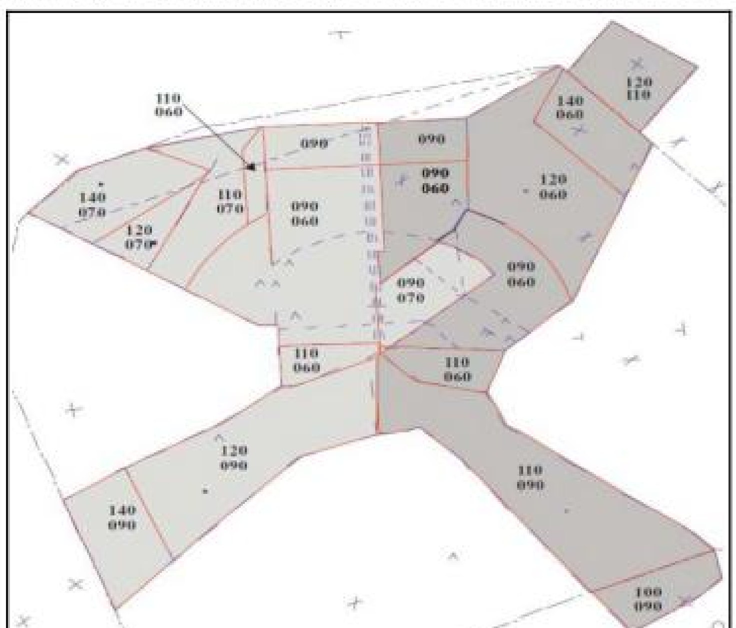
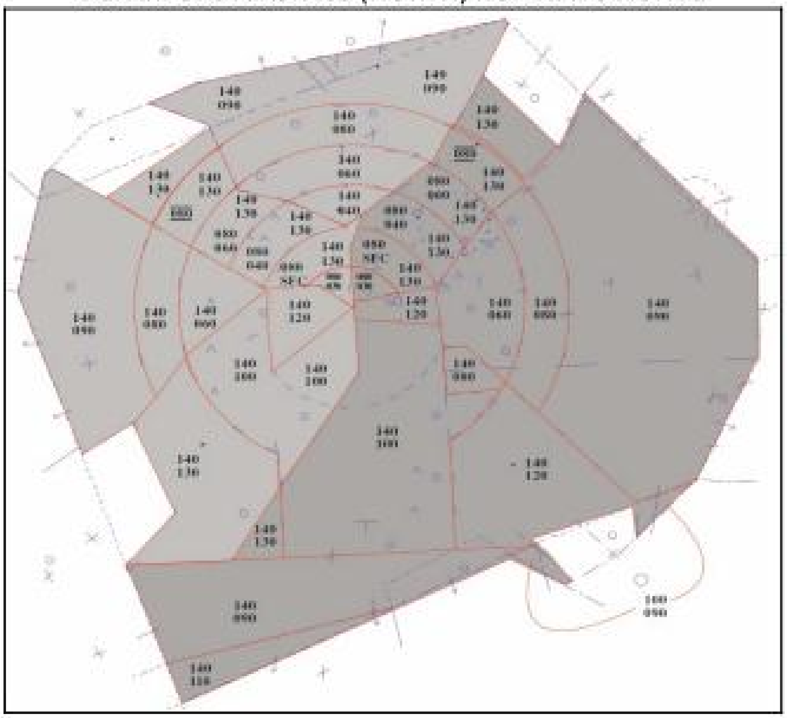


Figure 24. Airspace delegation for arrivals in the south direction at CLT [6]

DEPARTURE AIRSPACE (NORTH) RUNWAY 5 ACTIVE



DEPARTURE AIRSPACE (NORTH) RUNWAY 5 INACTIVE

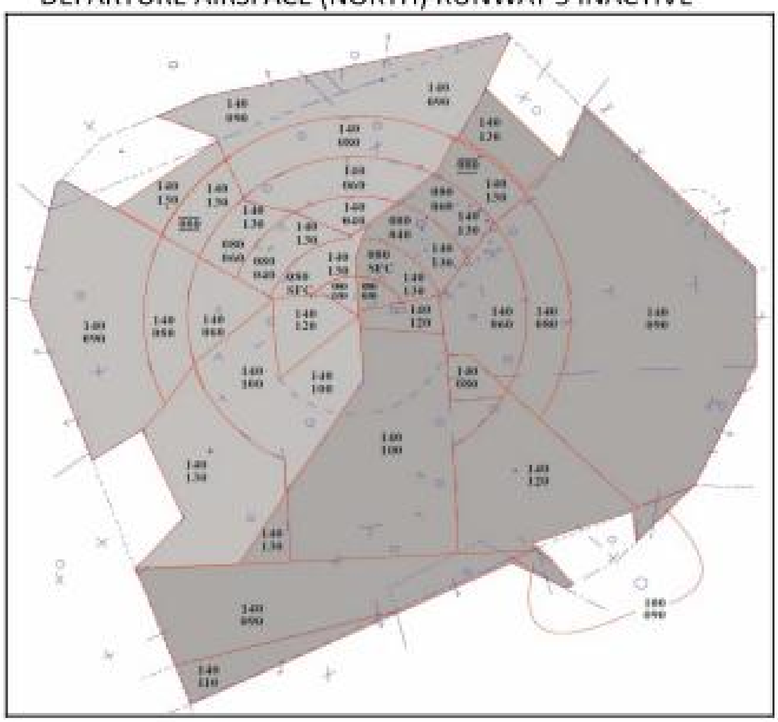
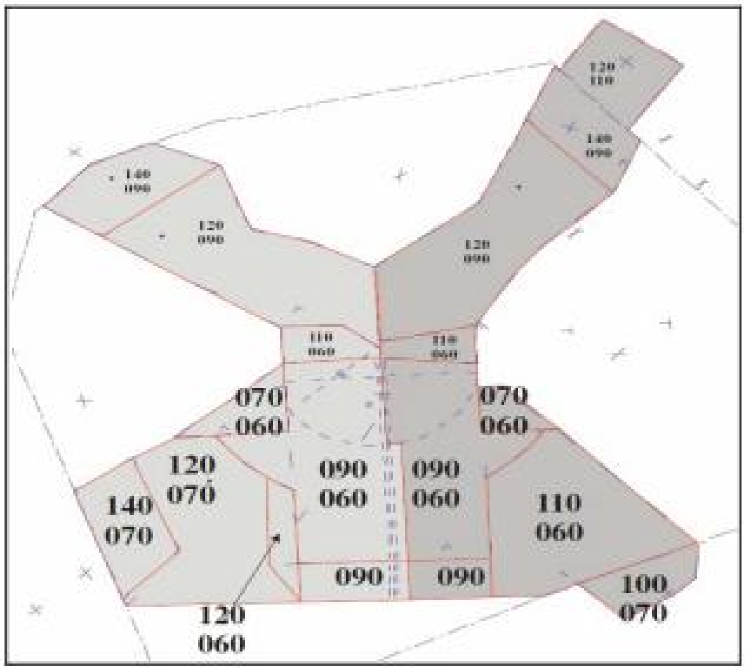


Figure 25. Airspace delegation for departures in the north direction at CLT [6]

ARRIVAL RADAR EAST/WEST AIRSPACE (NORTH OPERATION) RUNWAY 5 INACTIVE



ARRIVAL RADAR EAST/WEST AIRSPACE (NORTH OPERATION) RUNWAY 5 ACTIVE

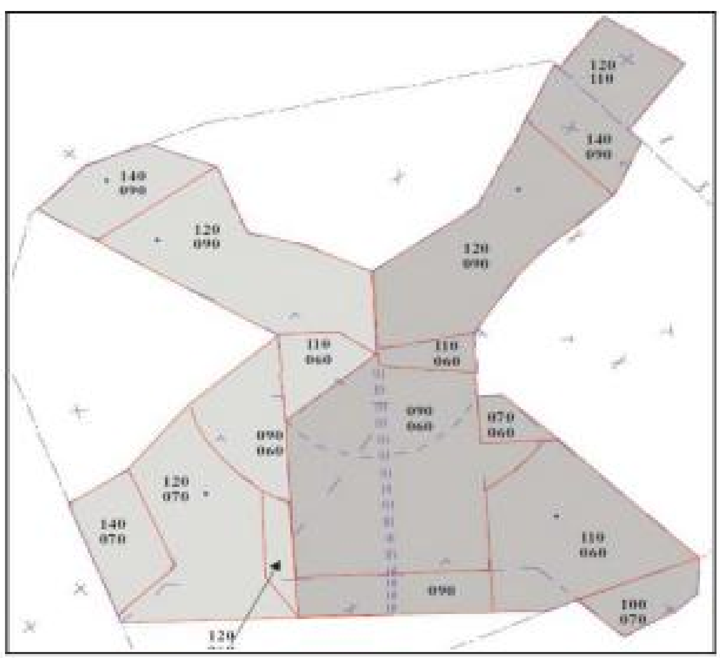


Figure 26. Airspace delegation for arrivals in the north direction at CLT [6]

As can be seen from the airspace delegation figures above CLT is designed as four corner posts, with arrivals approaching from the four corners and departures climbing through the sides. In the southern flow configuration, the arrivals from the north corners (the shorter side) can approach as low as 7000 and 6000 feet. The arrivals from the south (with the longer downwind leg) approach as low as 9000 feet, descend to 6000 feet on the downwind, and finally merge with the flow from the north. Departures stay below the arrivals on the southern side, climbing only to 8000 feet. As they loop north they climb above the northern arrivals maintaining above 10000 to 13000 feet depending on the airspace region. This process often leads to the leveling off of departures and arrivals to maintain their altitude limits as designed by the airspace delegation. This was pointed out as one of the inefficiencies in current operations in the OAPM study report as shown in Figure 27 below.

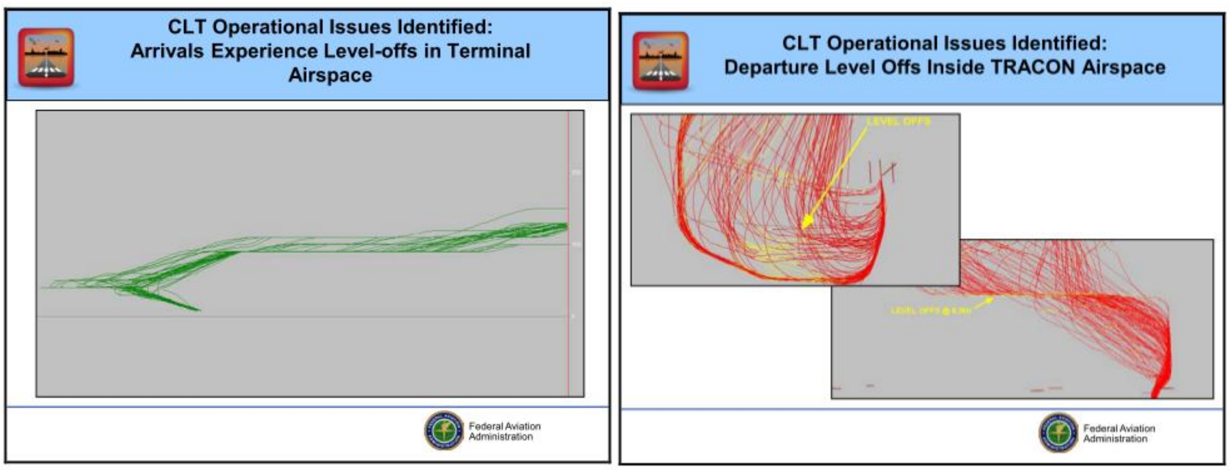


Figure 27. Arrival and departure level off in the TRACON at CLT [3]

CLT has pre-arranged coordination areas in which the departures can penetrate the arrival airspace under the control of the departure radar controller, who is responsible to maintain separation from the arrivals. The arrival controller points out traffic to the departure controller, obtains altitude read outs from the aircraft under the departure control, and can terminate the pre-arranged coordination as needed. This procedure indicates significant interaction between the arrival and departure flows. The departure controller maneuvers the departures in the arrival airspace if needed to maintain continuous climb and to reduce the travel distance to the destination through short cuts. It will be confirmed through SME input if the arrivals are typically maneuvered as well in coordination with the departure controller.

[Potential application: The pre-arranged coordination between the arrival and departure flows may be supported by scheduling of arrivals and departures at pre-designed intersection points along multiple route options connecting the arrival and departures standard routes.]

Figure 28 below from the OAPM study report shows track data for the arrival and departure flows in the northern flow and some of the interactions between them. Some of the other inefficiencies identified in the OAPM study are lack of sufficient arrival and departure routes and transition points, large airspace gaps between the arrival and departure flows resulting in excessive loops, and long common segments because of late divergence for departures and early merges for arrivals.

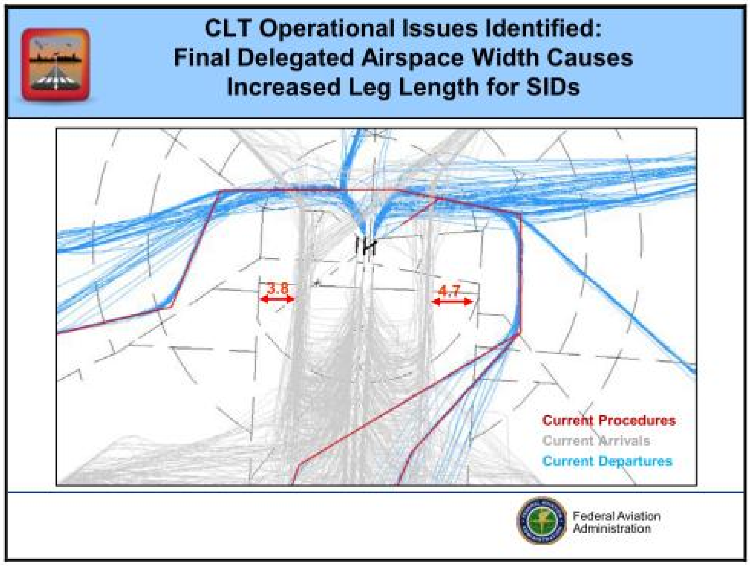


Figure 28. Arrival and departure flow interactions at CLT [3]

The OAPM study recommended new designs that mitigate some of these issues by adding dual STARs and multiple departure transition points. A notable example is shown in Figure 29 for the arrivals and departures in the northwest corner. Dual STARs are created instead of a single STAR to provide more route options for the arrivals and delay their merge. The STARs are sufficiently separated to insert a departure route in between. As can be seen from the tracks of the northbound departures, many of these flights turn to the left after they exit the terminal area through the northern side. The SID through the northwest corner gives these flights a much shorter route option and large benefits. The OAPM study includes an alternative option without the SID route between the two STARs because this design may not be acceptable.

[Potential application: This example provides an interesting case for investigating how to enable a more distributed set of transition points (along the boundary of the terminal airspace) through integrated scheduling]

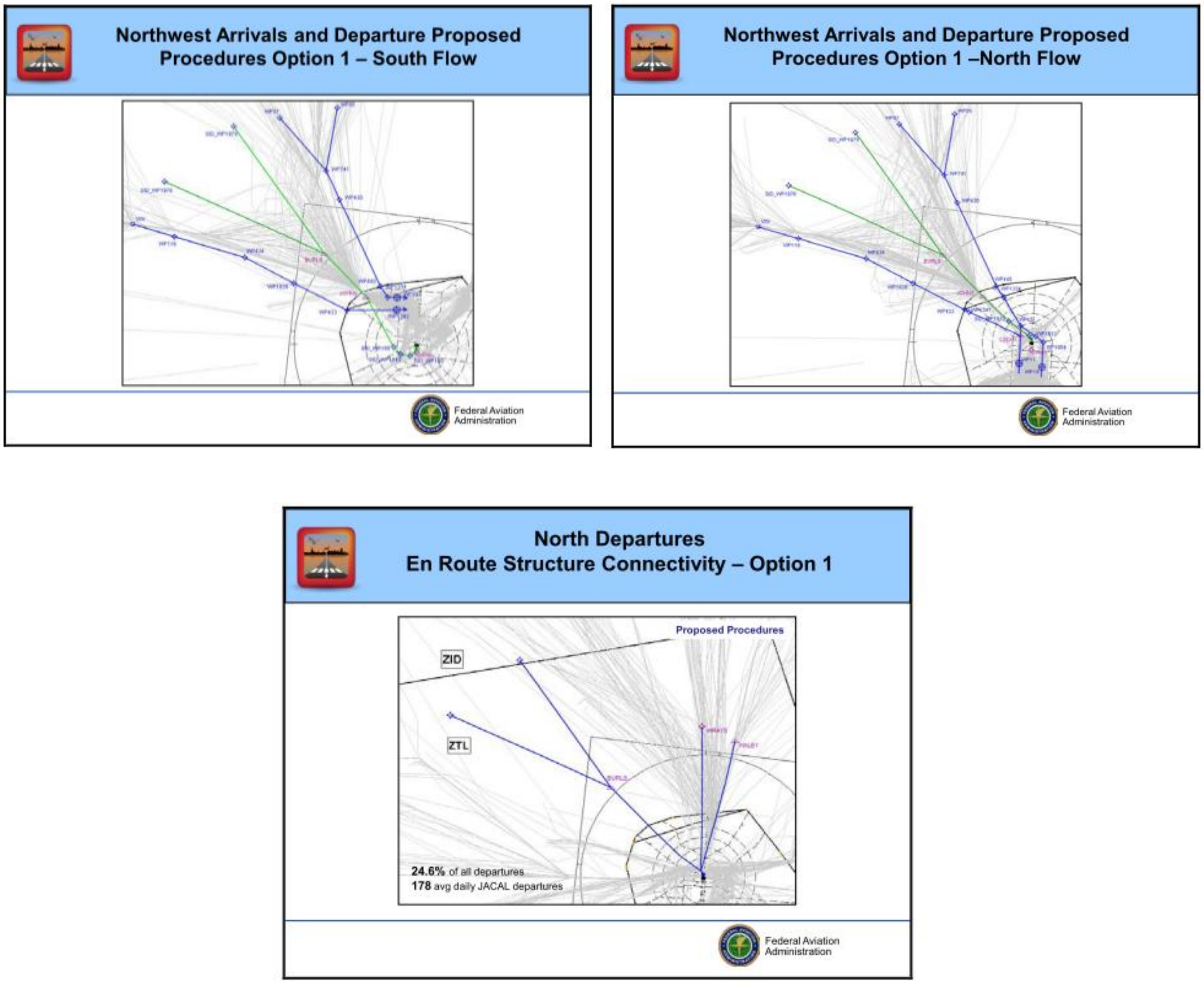


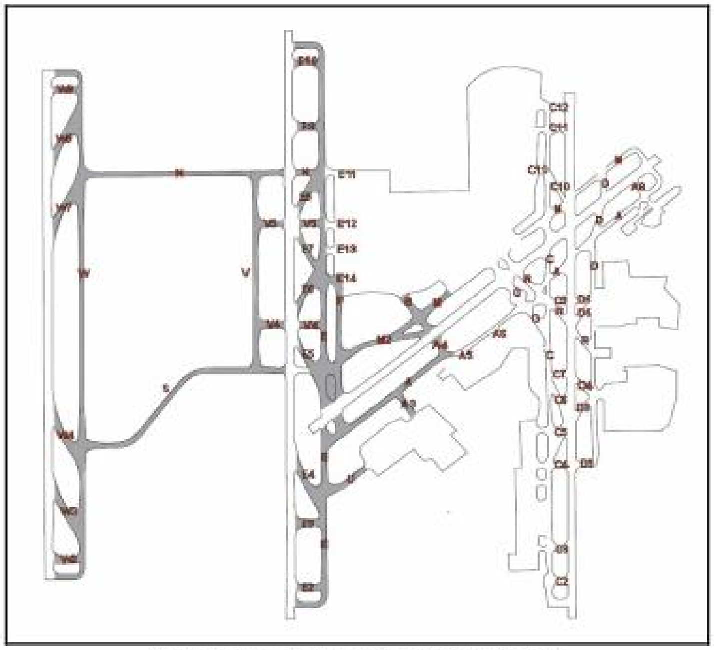
Figure 29. Arrival and departure interactions in the northwest corner at CLT [3]

Runway interactions

CLT has four runways as shown in Figure 30. Runways 18L/36R, 18C/36C, and 18R/36L are three parallel runways. Runway 23/5 crosses runway 18L/36R and converges on the other two runways. Local east controls runways 23/5 and 18L/36R and local west controls runways 18L/36R and 18C/36C. Departures are typically conducted from the east runways 18L/36R, 18C/36C, and 5/23. CLT has the ability to use either two or three runways for arrivals in each direction. This enables adjusting the capacity to match the demand.

[Potential application: This enables for example, scheduling either arrivals or departures on a runway exclusively for a period of time to match the demand.]

The runway interactions at CLT also provide the ability to analyze both independent operations when Runway 5/23 is inactive as well as dependent operations when it is active.



GROUND AREA OF JURISDICTION

NOTE: GRAY IS GND "WEST", WHITE IS GND "EAST".

Figure 30. CLT airport diagram and ground control delegation [6]

The headings from the runways are assigned mainly by noise tracks for turbojets. According to the SOP, there are many restrictions and instructions for heading assignments when crossing the path of another runway. SME input will be inquired as to the limitation that this imposes on the operations.

Taxi and ramp interactions

Ground control is divided into two control positions east and west as shown in Figure 30. According to the SOP, the ground controller is assigned significant release coordination (APREQ) activities: All 5/23 departures have to be coordinated before taxiing. All departures from 18R/36L have to be coordinated with local west prior to taxiing. All departures from intersection points have to be coordinated with the appropriate local controller. Additional SME input is needed to assess ramp and taxi interactions.

The NOCAL case

The main sources of the analysis of the NOCAL case are the OAPM study [4], and navigation arrival and departure routes and SOPs available online [8]. SME input will be obtained to confirm or adjust this analysis.

Interactions between arrivals and departures are highlighted under the following categories:

a. Airspace interactions
b. Runway interactions
c. Taxi and ramp interactions

Airspace interactions

The NoCal airspace has two configurations: west and east. The descriptions of the arrival departure interactions below are focused on the west flow which is more common (over 90 percent of the time according to the OAPM study [4]). The corresponding airspace delegations are shown in Figure 31. The interactions are also focused on the three major airports: San Francisco (SFO), San Jose (SJC), and Oakland (OAK).

In the west flow, the Richmond airspace handles both arrivals and departures where there is significant sharing of routes among the airports. For example, Richmond handles the GOLDN and BYE northern arrivals to both SFO and SJC, where SFO arrivals are handed off to Woodside at 8000 feet and SJC arrivals to Licke at 9000 feet. It also handles OAK northern arrivals over RAIDR and hands them off to Grove at 4000 feet. Oceanic arrivals to all three airports are also handled by Richmond, where they are handed off to Woodside at 8000 feet over OSI (to SFO and OAK) and at 7000 feet to SJC. Woodside in turns hands these flights while descending to Grove (OAK) and Licke (SJC). In addition, Richmond handles the SFO and OAK departures, which are maintained below the arrival streams.

The Woodside airspace handles SFO approach. It underlies part of the Licke airspace which handles SJC approach and departures. As a result it has to maintain its arrivals (mainly from the east) at or above 6000 feet until past the SJC departures maintained below 5000 feet by Licke. The following are example quotes from the SOP:

“MOD# arrivals are received from Grove descending to 7000. These aircraft shall be vectored to the final approach course. Use caution to keep aircraft at or above 6000 until past SJC departures.”

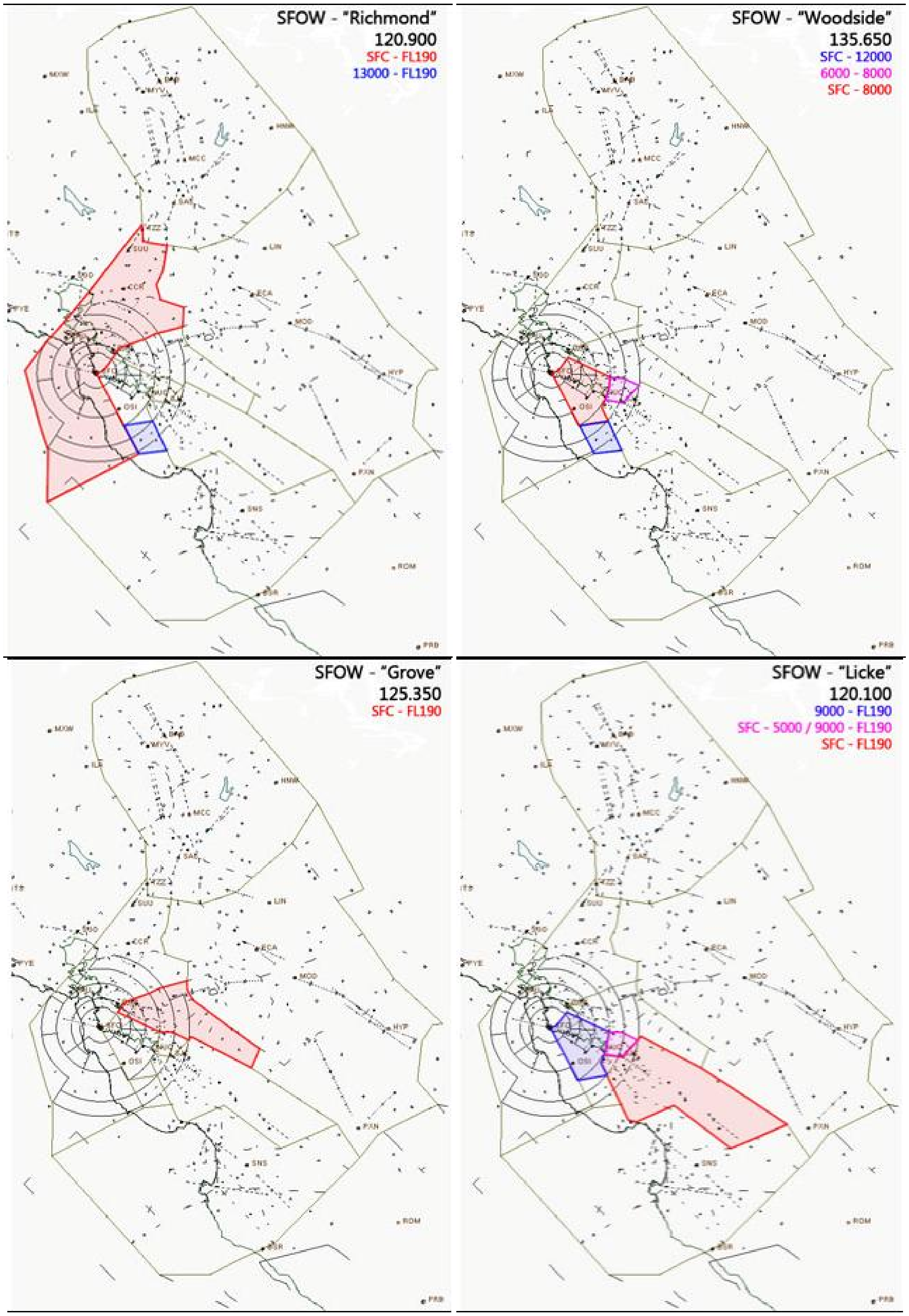


Figure 31. Airspace delegation in the NoCal west flow [8]

"RISTI# arrivals are received from Grove heading 240 and descending to 7000. These aircraft shall be vectored to the final approach course. Use caution to keep aircraft at or above 6000 until past SJC departures."

"YOSEM# arrivals are received from Grove with instructions to cross FAITH at 7000 and 210kts. Once aircraft are received, they shall be vectored to the final approach course. *Use caution to keep aircraft at 6000 until past SJC departures."*

In addition the Woodside airspace descends SJC from PYE to 4000 feet and hands them off to Licke and the OAK oceanic arrivals to 6000 feet handing off to Grove.

The Licke airspace handles SJC approach and departures. It has significant interactions with the SFO flows where it has to maintain its departures below 5000 feet to avoid the SFO approach. The following are excerpt examples from the SOP:

"GOLDN# arrivals are received from Richmond at 9000 with instructions to depart SFO on heading 120. Once clear of the underlying Woodside airspace, aircraft shall be descended and vectored to a downwind leg. A point out may be requested to descend the GOLDN# stream below the shelf over Woodside sector to 7000 for a visual approach to runway 30L from the left downwind, but only if it will not conflict with the BSR# stream to SFO."

"LOUPE# shall proceed under pilot navigation; These aircraft must remain at or below 5000 per the departure instructions to pass beneath the SFO runway 28 final approach stream. Once clear of the SFO 28 approach stream, aircraft shall be cleared to climb to FL190 and vectored back to SJC to resume the departure. A fixed point out shall be maintained with Grove for aircraft climbing on the departure."

"SJC# departures must remain at or below 5000 per the published runway departure instructions to pass beneath the SFO runway 28 final approach stream. Once clear of the SFO 28 approach stream, aircraft shall be cleared to climb to FL190."

The Grove airspace handles primarily the OAK approach. It also handles the SFO streams from the east and hands them off to Woodside. These streams interact with the SJC departures and have to be maintained above 7000 feet prior to handoff to Woodside. The following is an excerpt example from the SOP:

"MOD# arrivals for SFO are received from Valley with instructions to cross CEDES at 11000. Descend these aircraft to 7,000 to clear the PXN# stream then hand off to Woodside. *To protect SJC departures, the MOD# arrivals must not be descended lower than 7000 prior to hand off to Woodside."*

[Potential application: The interactions (crossing and sharing) among the arrival and departure flows of the three airports warrant considering for integrated scheduling.]

The following three figures 32-34, from the OAPM study of NoCal, show the interactions between the arrivals and departure flows using track data, current STARs and SIDs and the recommendations made by the OAPM study [4]. The figures show respectively the flows in the north, south and east sides of the airspace. Each figure contains the departure flow on the left and the arrival flow on the right, for SFO on the top, OAK in the middle and SJC at the bottom. The following observations are made about arrival departure interactions:

The first figure 32 shows the arrival flow from the north over the Golden gate STAR for SFO and SJC, and the RAIDR STAR for OAK. The arrival routes from the north clearly avoid the departure flows to the north and east by making a long loop towards the west. There are many arrivals from the north east that would fly a shorter route if they approached from the east rather than from the north. The OAK RAIDR flow and SJC flow show that some flights decided to do so and point out a possible multi-route option. Further SME input is needed to determine the reason for the current design and allocation of flights. This figure also sows the sharing of the departure exits among the airports.

The following figure 33 shows the interactions between the arrival and departure flows of the three airports in the southern side. There is a clear interleaving between the arrival and departure routes, which is accomplished by significant kinks that lengthen the routes. The flight tracks show significant amount of short cuts in both the arrival and departure flows. These short cuts can benefit flights when they can cross or share airspace or routes of other streams.

The last figure 34 shows the arrival routes from the east for the three airports. Some of these routes are shared among the airports. A significant amount of shortcuts can be observed. The multi-route option between approaching from the north or from the east can be seen in this figure as well.

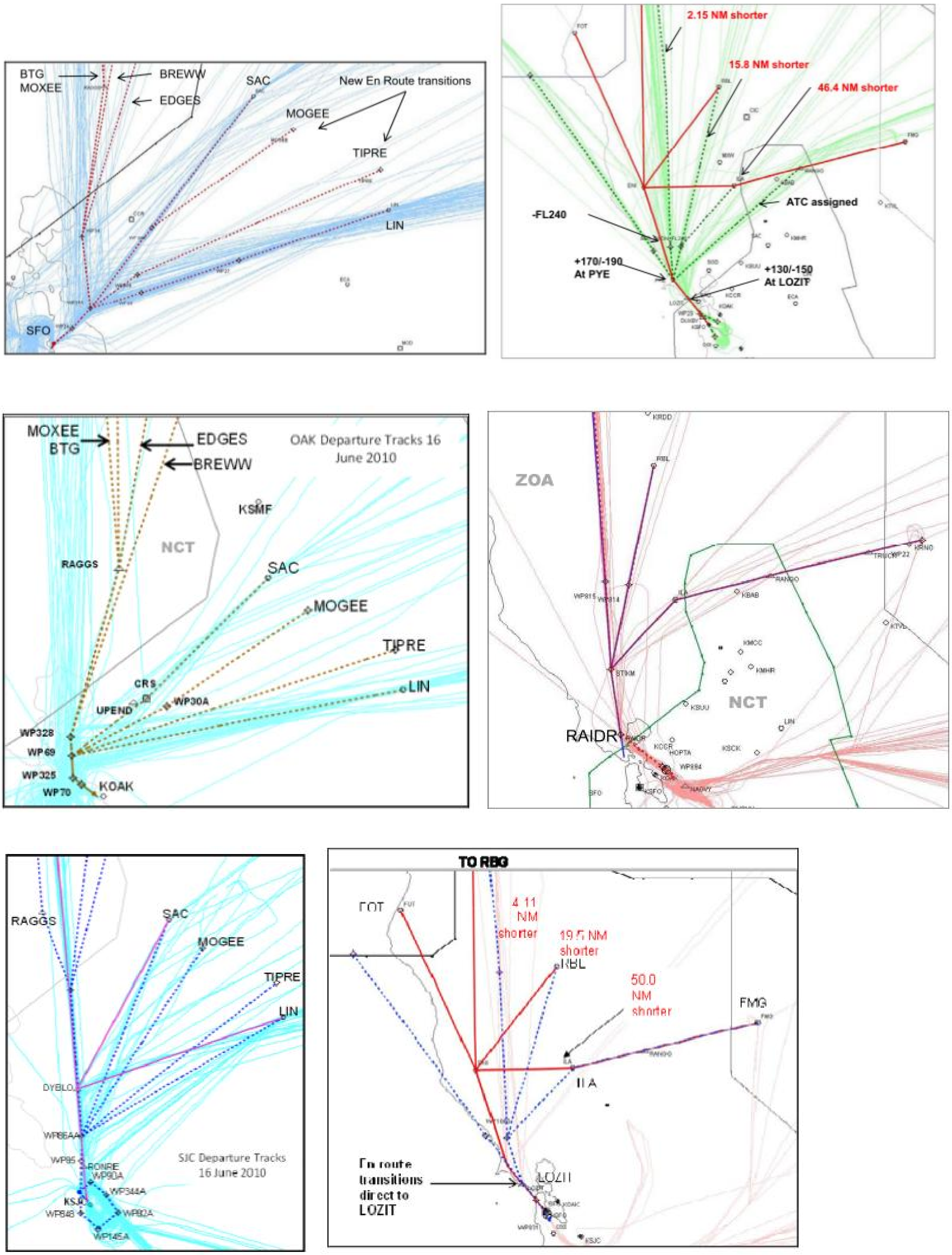


Figure 32. Interactions between northern flows of NoCal airports [4]

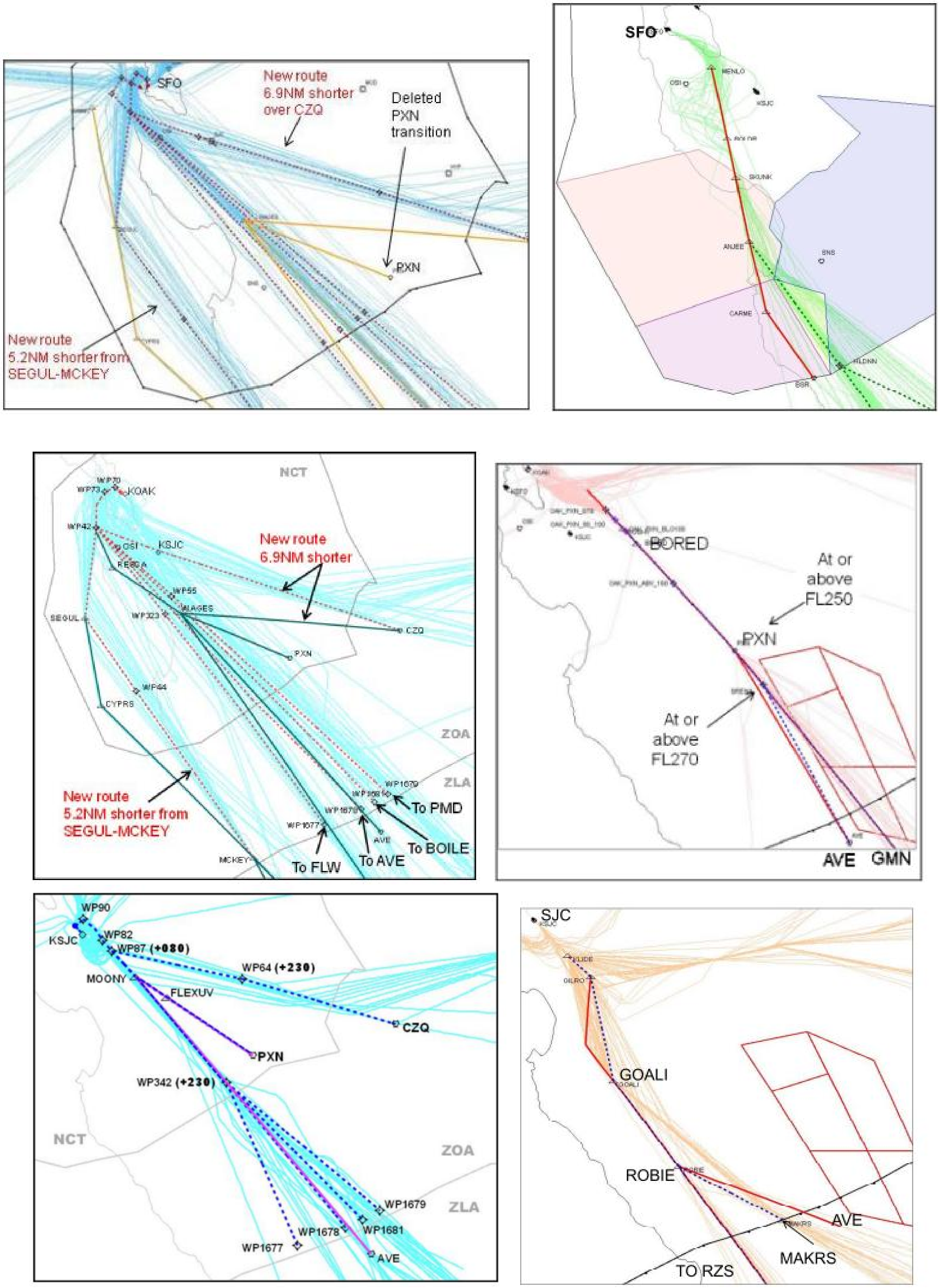


Figure 33. Interactions between southern flows of NoCal airports [4]

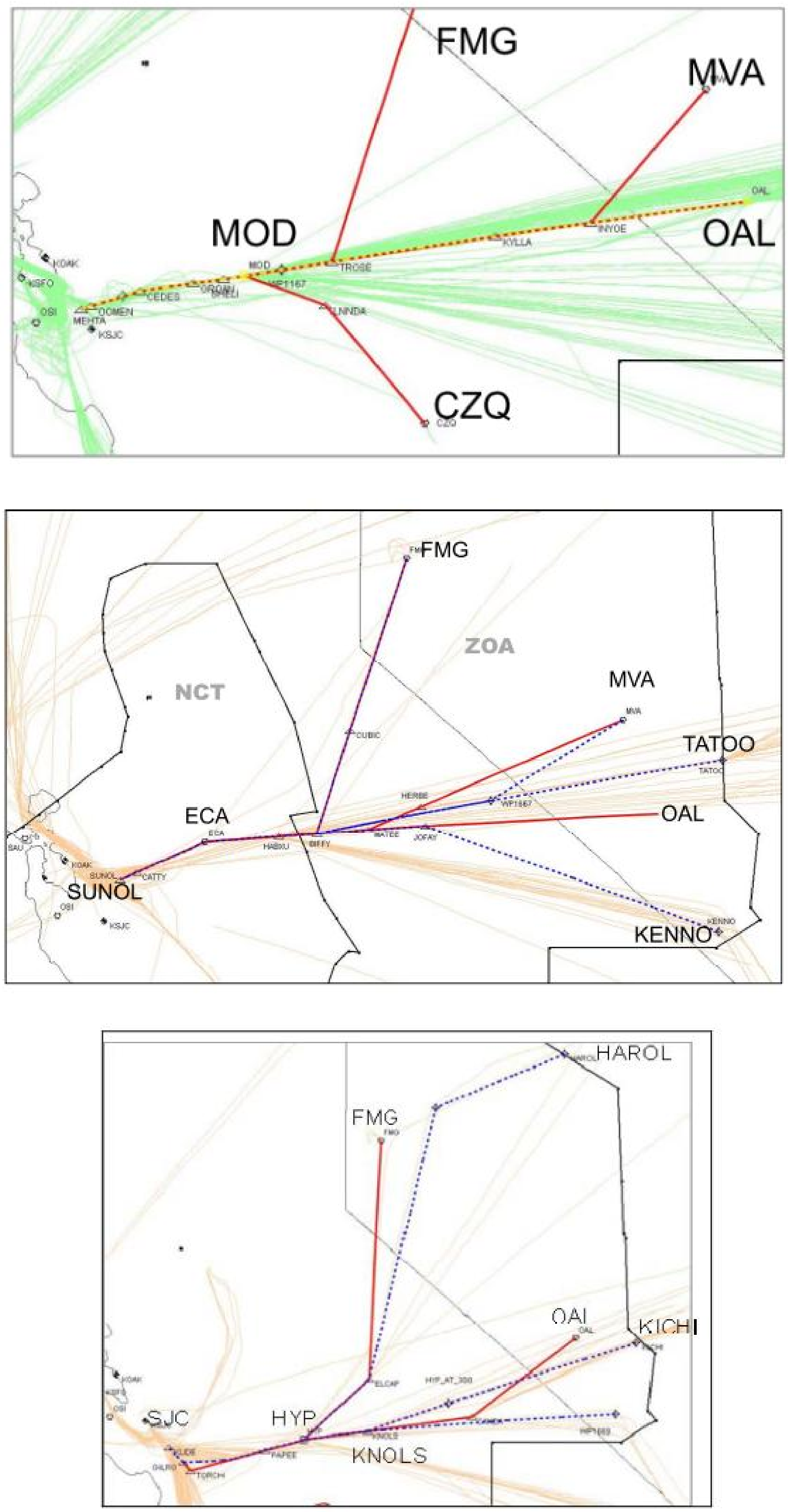


Figure 34. Interactions between eastern flows of NoCal airports [4]

One observation is that the OAPM study proposed segregating the STARs that are currently shared among SJC, OAK and SFO from the east. For example, as can be seen in Figure 34, OAL was used by all airports in the current procedure, but in the new design would be reserved for SFO and additional transition points are introduced for OAK (TATOO) and SJC (KICHI). This was also done in general for the other flows from the north and the south. Segregation is done by introducing additional transition points and routes, which is beneficial in terms of increasing capacity and flexibility. However, there is a benefit in sharing routes and fixes. For example, one airport with a peak demand may use the additional routes designated for another airport when that airport is experiencing a lull in demand. This practice may be occurring currently by sharing the STARs.

[Potential application: The new OAPM designs offer additional routes and transition points but reduce sharing. An investigation into maintaining both the added routes and the ability to share them may be investigated through integrated scheduling. The OAPM study focused on either arrival or departure flows exclusively, but some of the transition points added may be considered for shared use or additional points/routes may be added. Further SME input is needed]

Runway and ramp interactions

The diagrams of the three major airports SFO, OAK, and SJC are shown in Figure 35 below. Two major flow directions are used in the NOCAL TRACON: West which is the dominant flow and east/southeast. In the west direction SFO lands on 28L/R and departs 1L/R and 28L/R. SJC lands and departs on 30L/R. OAK lands and departs on 29 and 27. This configuration is used about 90 percent of the time according to the OAPM study [4].

SFO features intersecting arrival and departure runways and hence a significant coupling between arrival and departure runway operations. Independent visual landings are performed on 28L/R. SJC has two closely spaced parallel runways and hence also features dependent arrival and departure runway operations. SFO is the largest and most congested of the airports and hence it is suggested that it is used as the focus of the concept development for inetgrating runway and surface operations, while the other two airports serve as secondary airports.

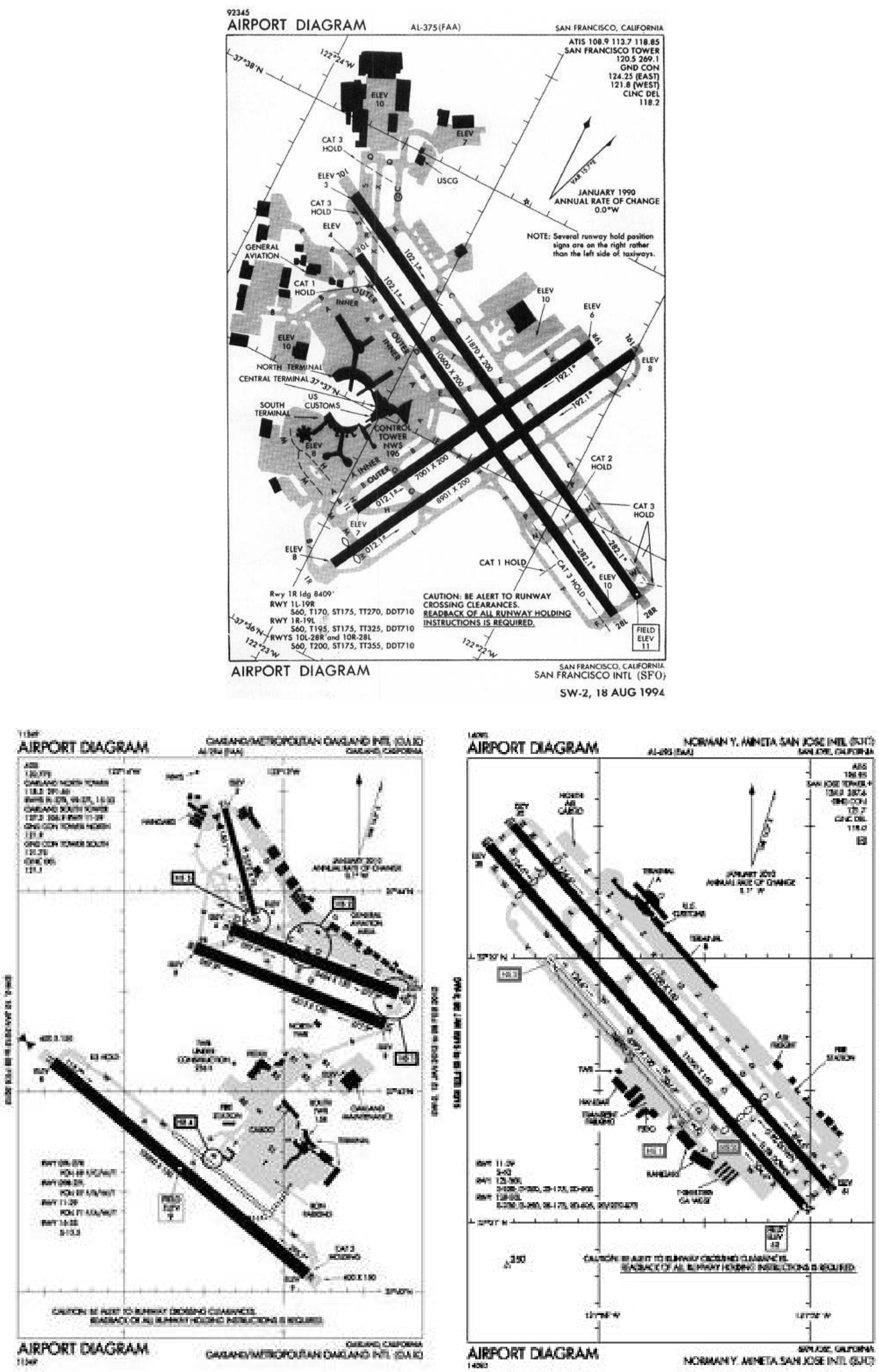


Figure 35. Diagrams of the major NoCal airports

According to the SOP, departures on 1L and 1R are assigned based on heading: headings to the right on 1R and to the left on 1L. Heavy departures to Europe, Asia, and the Middle East shall be assigned runway 28R/10L for departure.

Taxi and ramp interactions

As shown in the excerpt in Figure 36 from the SOP, SFO has multiple taxi lanes in most ramp areas. each ramp area has defined taxi spots where aircraft are introduced into the movement area. According to the SOP some of the gates pushback onto taxiway alpha and are instructed to call for pushback.

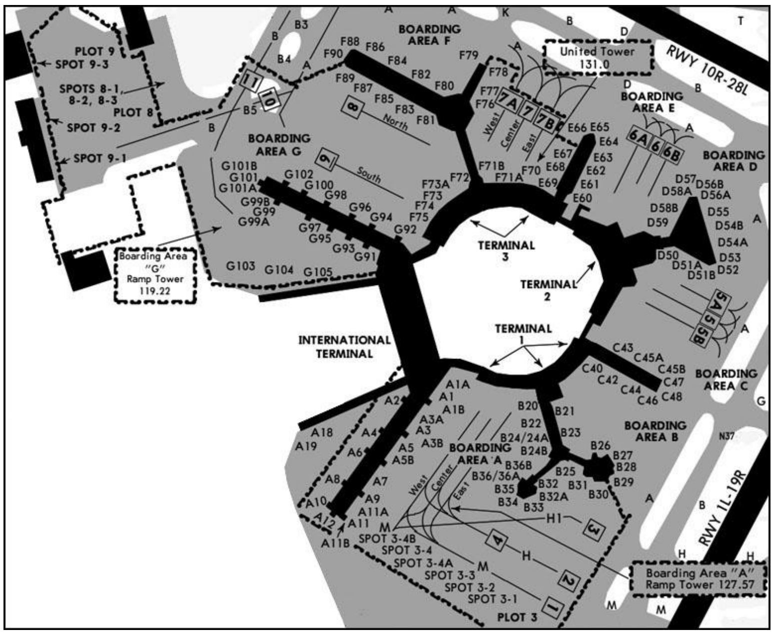


Figure 36. Interactions between northern flows of NoCal airports [8]

The SOCAL case

The main sources of the analysis of the SOCAL case are the Tower and TRACON SOPs available online [9]. SME input will be obtained to confirm or adjust this analysis.

Interactions between arrivals and departures are highlighted under the following categories:

a. Airspace interactions
b. Runway interactions
c. Taxi and ramp interactions

Airspace interactions

The LAX approach flows and the airspace delegations are shown in Figures 37 and 38, respectively, in the west direction, which is the normal flow in SoCal. The approach flows indicate the following interactions between arrivals and departures and opportunities for the application of airspace sharing/scheduling and multiple routes. Some of these opportunities seem to be currently practiced as indicated with dotted lines in Figure 37.

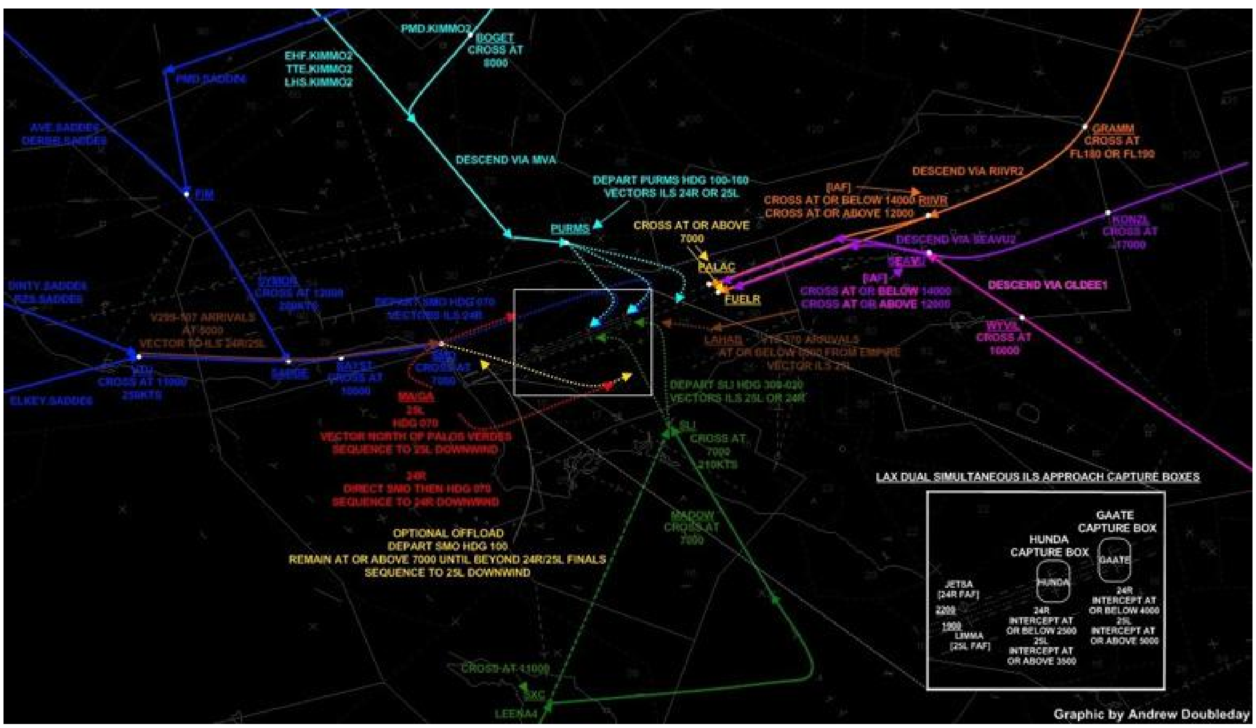


Figure 37. LAX approach in west flow [9]

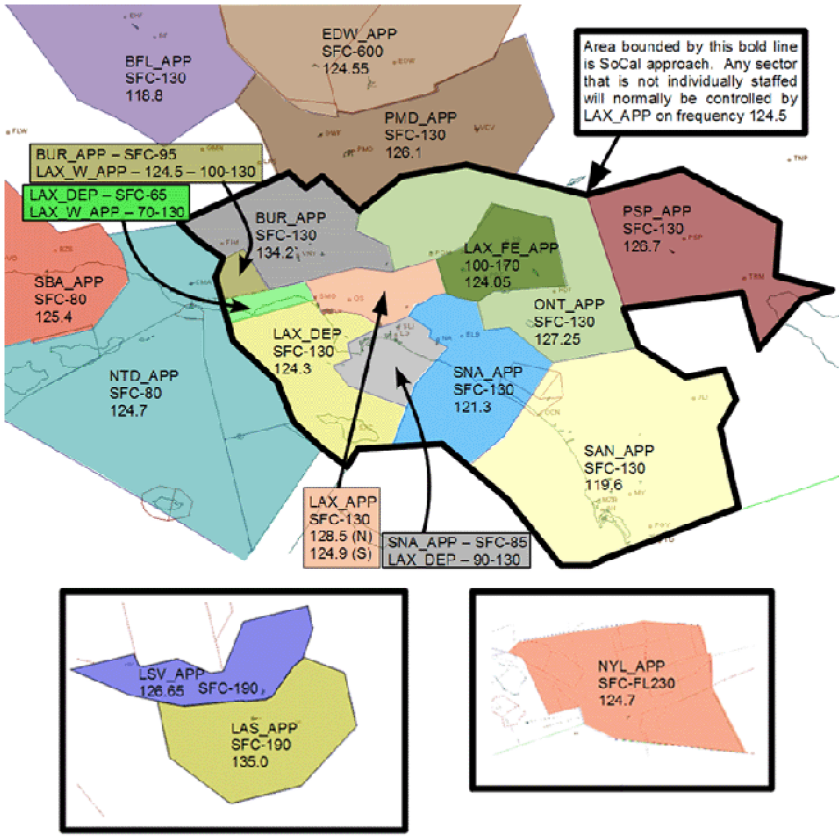


Figure 38. Airspace delegations in SoCal terminal [9]

1. The arrivals from the southwest are path stretched towards the eastern side and approach the airport from the southeast rather than the southwest corner as shown in Figure 37. This may be (to be confirmed with SME input) practiced in order to avoid the departures who own the airspace to the west, southwest, and south of the airport up to 13000 feet (as indicated in Figure 38), allowing continuous climb. It may also be practiced to avoid the approach to SNA which owns the airspace south of the airport up to 8500 feet as indicated in Figure 38. A dotted line in Figure 37 shows that a short cut route is available to these arrivals to reduce the path stretch to the east. The availability of this short cut may be based on the departure and SNA traffic intensity and the possibility of sharing this airspace without impacting the continuous climb of departures.

   [Potential application: Integrated scheduling may be used to coordinate the multi-route option apparently available from the southeast].

2. The arrivals from the north, west, and northwest approach the airport from the northwest corner and merge onto a downwind on the upper side of the runways. A

dotted line in Figure 37 shows an opportunity to offload some of these arrivals to the southern side, crossing above the airport.

[Potential application: Currently this offload does not seem to interact with the departures but a multiple route option may be developed and coordinated with the departure flows].

3. The departures on the GMN and CASTA SIDs remain below 6000 feet under departure control, to remain below the arrivals SADDE stream from the northwest. Prearranged point outs are used to continue to climb these aircraft above 7000 in the LAX west approach airspace.

   [Potential application: This offers an opportunity for coordinated scheduling of arrivals and departures to enable continuous profiles and shorter travel].

   The following are example excepts from the SOP [9]:

   - "If North Approach gets too busy to handle traffic west of SMO, LAX_W_APP should open to merge VTU.SADDE6 and FIM.SADDE6 traffic. LAX_W_APP owns a shelf above the western area of BUR_APP from 10,000 to 13,000' inclusive, and a shelf from 7000-13,000 above the northern portion of LAX_DEP as shown on the diagram. Optionally, LAX_W_APP can combine with LAX_DEP and handle all arrivals until SMO VOR, and all departures."
   - "LAX_DEP may climb aircraft on the GMN4 departure into LAX_W_APP airspace once they are north of the SADDE6 arrival stream so long as LAX_DEP performs an automated pointout with LAX_W_APP at least one minute prior to the aircraft initiating a climb above 6000'."
   - "GMN departures shall be vectored north towards the LAX 323 radial. Aircraft shall be handed to BUR APP, climbing to 6000 on a heading of 360 for further climb and vectors to the LAX R-323. Traffic calls are mandatory to the LAX downwind traffic descending to 7,000. Departure has a prearranged pointout with LAX APP to climb aircraft higher than 6,000 when the SADDE6 corridor is clear. The higher altitude shall be coordinated with BUR APP prior to the handoff."
   - "CASTA departures fly a pilot nav route to GMN, EHF or AVE. The MEA on the SID is 6200' initially. When LAX_W_APP is owned by another controller, LAX_DEP must restrict these aircraft to 6000'. CASTA departures should be vectored off the route to eliminate the MEA conflict. LAX_DEP should also consider negotiating a standing

pointout arrangement with LAX_W_APP that would allow the aircraft to be climbed higher than 6000'."

The east direction poses more challenges to the departure and arrival interactions, although it is not a nominal operation. Figure 39 shows the arrival flows. The main challenge is described in the following excerpt from the SOP: "During east operations, the challenge is to climb aircraft on runways 6R and 7L no higher than 7000 feet under the BASET arrival stream, to turn them onto the appropriate heading, and to hand them off to the appropriate facility". The following are two example departure procedures as described in the SOP:

- "GMN departures are altitude restricted to 7000 until safely north of the BASET arrivals, turned left to a heading of 290 to intercept the VNY 126 radial, and when safely north of the BASET2 arrival stream, including the SMO variant, handed to BUR APP. BUR has control for climb."
- "VTU departures are altitude restricted to 7000 until safely south of the BASET arrivals. They are climbed on runway heading until approximately 3 miles past REEDR intersection, turned right to a heading of 210 to parallel the southwest bound BASET arrivals, and once separated from the southwest bound BASET arrivals, climbed to 13000. Once above the southwest bound BASET arrivals, they are turned to a heading of 250 and handed off to LAX_A_CTR."

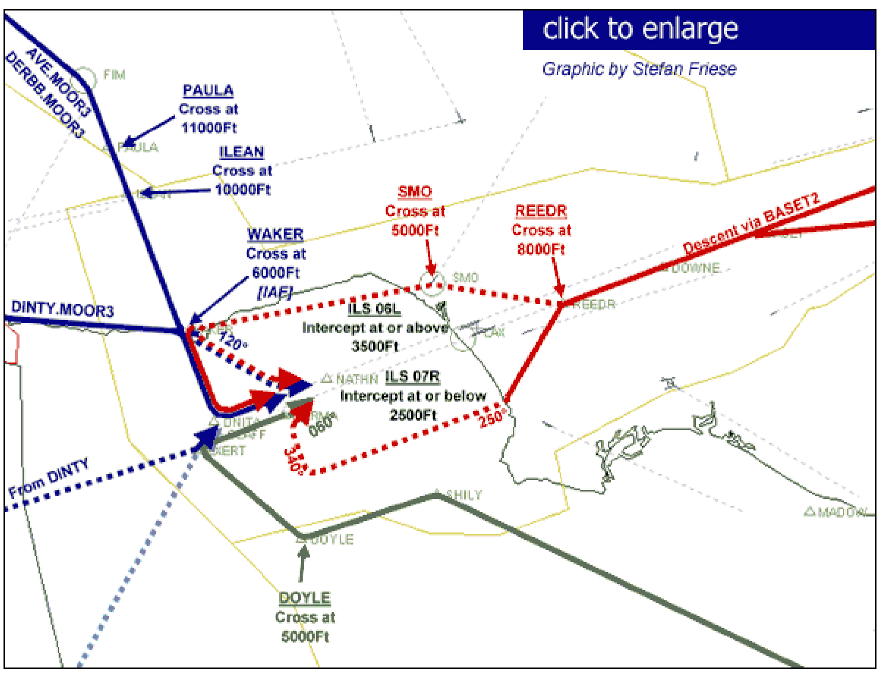


Figure 39. LAX approach in east flow [9]

Runway and ramp interactions

The LAX airport diagram is shown in Figure 40. The airport features a modern surface layout similar to ATL, with two parallel runway complexes on either side of the terminal buildings. Unlike ATL, LAX does not include taxiway loops around the runways to avoid runway crossing. It also does not have access from the ramp areas to both runway complexes.

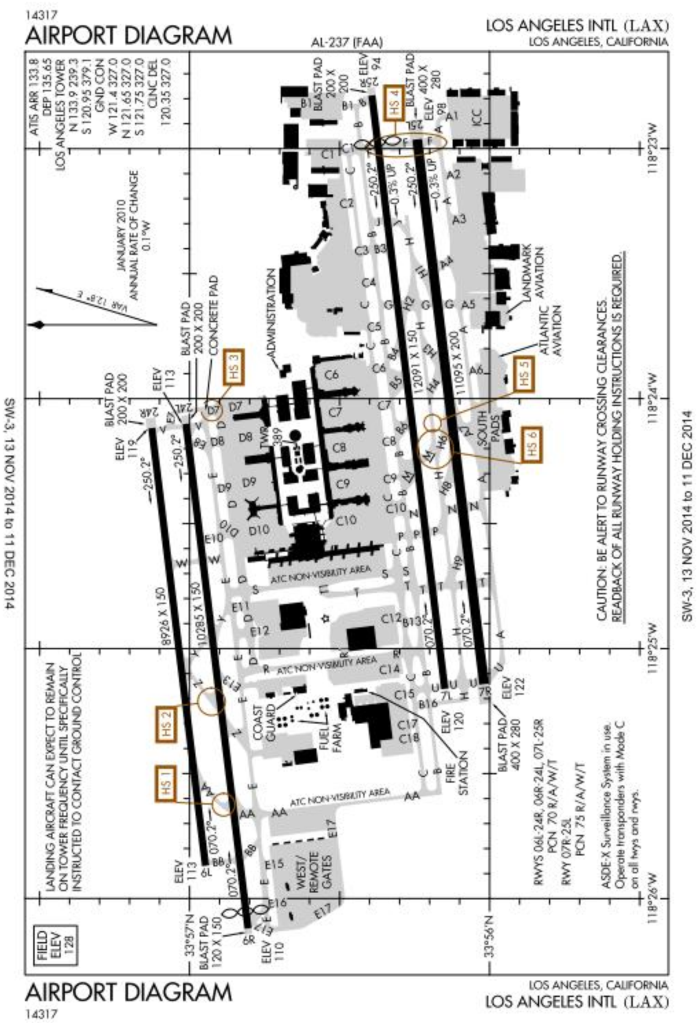


Figure 40. LAX airport diagram

The normal runway configuration LAX uses the following runway configuration:

25L - ILS and visual approaches (departures, if coordinated)
25R - Departures (visual approaches, if coordinated)

24L - Departures (visual approaches, if coordinated)
24R - ILS and visual approaches (departures, if coordinated)

According to the SOP, “when the airport is busy, aircraft should be assigned a departure runway based upon direction of flight. When the airport is quiet, aircraft may be assigned a runway based upon their location on the field”.

Ramp areas have well defined taxi spots at which aircraft are introduced into the movement area.

References

[1] FAA, Optimization of Airspace and Procedures in the Metroplex http://oapmenvironmental.com/oapm.html.

[2] FAA, Optimization of Airspace and Procedures in the Metroplex, Study Team Final Report, Atlanta Metroplex http://oapmenvironmental.com/oapm.html.

[3] FAA, Optimization of Airspace and Procedures in the Metroplex, Study Team Final Report, Charlotte Metroplex http://oapmenvironmental.com/oapm.html.

[4] FAA, Optimization of Airspace and Procedures in the Metroplex, Study Team Final Report, Northern California Metroplex http://oapmenvironmental.com/oapm.html.

[5] FAA Standard Operating Procedures, http://nyartcc.org

[6] FAA Standard Operating Procedures, http://vztlartcc.net

[7] Communication, site visits to ATL TRACON

[8] FAA Standard Operating Procedures, http://oakartcc.com

[9] FAA Standard Operating Procedures, http://laartcc.org