２．空港面交通管理のための羽田空港の駐機スポットに関する解析

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1. Introduction

The Electronic Navigation Research Institute (ENRI) is analysing surface movements at Tokyo International (Haneda) airport to create a simulation model that will be used to explore ways of relieving airport surface congestion. To faithfully reproduce congestion and allow us to investigate methods of reducing it, the simulation requires information on the spots (gates) used by flights and turnaround times (the time elapsed between an aircraft arriving at a spot and leaving the spot on its next flight).

Spot information is provided to ENRI for research purposes by the Japan Civil Aviation Bureau (JCAB). Data are obtained from two systems: the Spot Management and Planning (SMAP) system and the Online Data Archive Processor (ODAP). However, these are independent systems that derive spot data from different sources, and there are sometimes discrepancies between them. To create realistic simulation scenarios that can be used to examine surface congestion, it is necessary to process this spot data and to resolve automatically any discrepancies to the greatest extent possible.

In this paper, we examine the characteristics of SMAP and ODAP spot information and investigate the feasibility of using radar track data for spot determination. We also report on a preliminary analysis of turnaround times.

2. Data Sources and Processing

2.1 SMAP and ODAP Data

Spot data for Haneda airport are obtained from the SMAP and ODAP systems. SMAP is an air traffic flow management subsystem that collects spot operational information from each airport and provides it to air traffic flow management-related functions. The ODAP system is also a part of the air traffic flow management system, but details of its function are not publicly released.

Data from the SMAP and ODAP systems and flight plan data are provided in electronic files for seven days bimonthly. Flight plan data include each flight's callsign, aircraft registration number and aircraft type. Spot information includes the departure spot and various times: EOBT (Estimated Off Block Time), AOBT (Actual Off Block Time), EIBT (Estimated In Block Time) and AIBT (Actual In Block Time)[1]. Not all data are present for all flights, however.

2.2 Surface Movement Radar Data

Haneda airport's surface surveillance system is a multilateration radar that derives the position of an aircraft by comparing the time of arrival of signals from its transponder at different receivers. Data from the Haneda airport radar are processed by the Automated Radar Terminal System (ARTS). For each multilateration radar target, ARTS outputs a timestamp, a position and a "track number" at one-second intervals.

ARTS data are provided to ENRI by JCAB for the same days as SMAP/ODAP data. The received data are "smoothed" to reduce noise, and track numbers are correlated with other data to allow radar targets to be associated with flight plan, SMAP and ODAP records.

2.3 Determining Spot from Radar Data

For an aircraft to be detected and identified by a multilateration radar system its transponder must be switched on. Aircraft operators have been requested to turn on the transponder while taxiing at Haneda airport[2].

For departures, the transponder is typically switched on just before the aircraft is pushed back from the spot, and so the initial position of the radar track should be close to the spot.

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[1] Off block time is the time at which an aircraft departs the spot; in block time is the time at which an aircraft arrives at the spot.

[2] However, since the surface movement radar system is not formally used operationally, this is not mandatory.

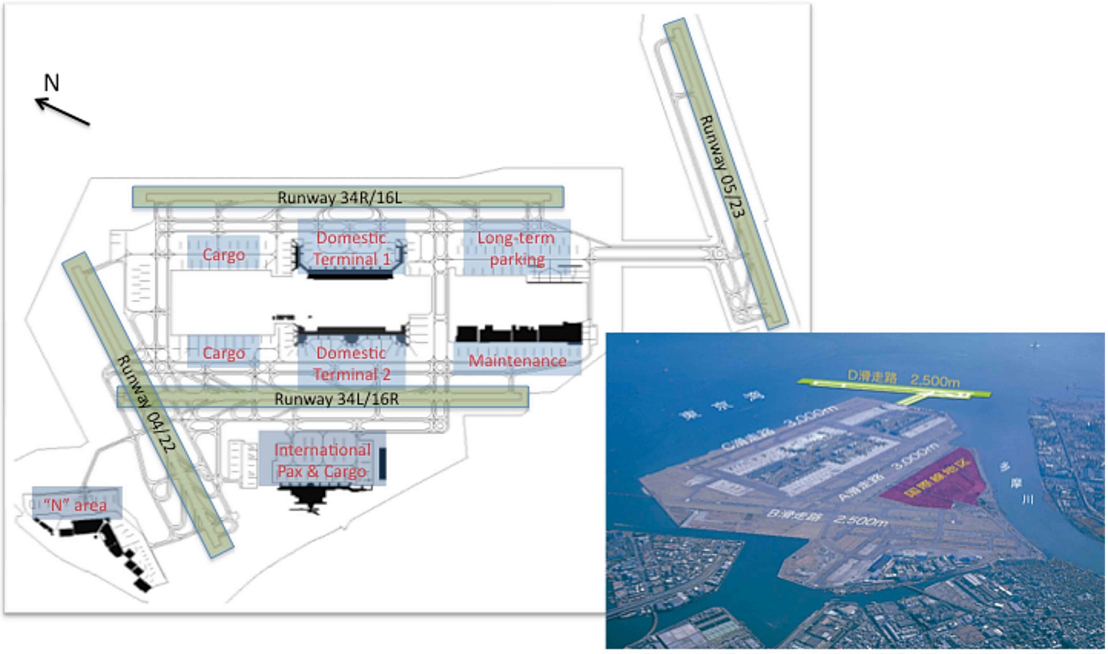


Figure 1 Haneda Airport Layout

2.3.1 Calculating Turnaround Times

The SMAP system provides records of AOBT and AIBT for each spot, along with flight plan details including callsign and aircraft registration. Since the callsign changes between flights, corresponding block in and block out records must be matched by aircraft registration number. Turnaround times for each spot are calculated as follows:

- For each aircraft registration number, collect AIBT/spot and AOBT/spot tuples and order them by time.
- For each pair of AIBT and AOBT in time order, if the spot is the same then compute the time difference AOBT–AIBT and add it to the list of turnaround times for that spot. (The block-in and block-out spots may differ if the aircraft has been towed.)

3. Analysis

3.1 Flight Categories

Different types of flights at Haneda airport park at different areas and follow different patterns of operation. For this analysis, flights departing Haneda airport were categorised as follows:

Domestic airline Japanese scheduled passenger carriers.

Foreign airline Foreign scheduled passenger carriers.

Domestic registration Japanese registered aircraft, non-airline ('JA' callsign prefix), including coast guard aircraft and business jets.

Government Japanese government flights, mostly navigation aid calibration aircraft.

Other Mostly foreign registered business jets.

The layout of Haneda airport is shown in Figure 1. Domestic airline flights primarily use the two domestic terminals, while foreign airline flights use the international terminal. Aircraft in the latter three categories primarily use the 'N' apron at the northwest corner of the airport.

3.2 Spot Data

SMAP and ODAP data for three weeks in May, July and September 2011 were analysed. The breakdown of flights for these periods is shown in Table 1. Of the 10,255 departures recorded, more than 95% were by domestic airlines, and just under 4% were by foreign airlines. The remainder (less than 2%) were 'JA' registration non-scheduled flights, calibration flights, and business jet flights.

Table 1 Haneda Departure Flights by Category

Category	Departures
Domestic airline	9,751 (95.1%)
Foreign airline	375 (3.7%)
Domestic registration	61 (0.6%)
Government	19 (0.2%)
Other	49 (0.5%)
Total	10,255

Table 2 shows SMAP and ODAP data availability. Both SMAP and ODAP departure spot records were available for more than 85% of departures. However, either SMAP or ODAP spot information were missing for more than 12% of departures, and around 2% of departures had no departure spot information.

Table 2 Spot Data Availability

SMAP	ODAP	Departures
有	有	8,783 (85.6%)
有	無	119 (1.2%)
無	有	1,130 (11.0%)
無	無	223 (2.2%)
	Total	10,255

The relationship between spot data availability and flight category was examined. For SMAP data, while most of the missing data were for domestic airlines (since these comprise over 90% of total traffic), less than 10% of domestic airline departures had no SMAP departure spot information and over 80% of the missing data were for flights by one particular carrier. Further, 15% of flights by domestic airlines departing from the International terminal were found to have no SMAP departure spot data. There were no SMAP data for nearly all other types of flights.

For ODAP data, less than 2% of domestic airline departures had no ODAP information. Moreover, ODAP spot information was available for more than 75% of foreign airlines and for more than 75% of 'Other' category aircraft (i.e. foreign business jets). In contrast, there was no ODAP spot information available for more than 70% of 'Domestic registration' flights and none for 'Government' flights. For foreign airlines, spot information availability depended on the airline, with data missing for nearly all departures by five of the 17 foreign airlines serving Haneda airport. Finally, no spot data were available for more than 70% of 'Domestic registration' aircraft and for any 'Government' flights.

We conclude that SMAP or ODAP spot data are available for the majority of departures from the domestic and international passenger terminals, although availability depends on the airline. For other categories of flights, spot information is limited but these flights comprise less than 3% of departures.

3.2.1 SMAP and ODAP Spot Agreement

We now examine cases where the SMAP and ODAP spot information disagree, and the feasibility of determining the spot from radar data.

When both SMAP and ODAP spot information were available, they were found to agree in over 98% of cases. For the cases where they disagreed, the spot data from each system were compared with the closest spot to the start of the aircraft's surface radar track. In more than 90% of those cases, the radar spot estimate agreed with the SMAP spot and disagreed with the ODAP spot. We therefore conclude that the SMAP spot data are more reliable than ODAP data. This agrees with the fact that SMAP data are derived from the Apron Management System and are supposed to provide a real-time picture of spot usage.

3.2.2 Radar Spot Estimate Accuracy

The assumption that SMAP spot data are accurate allows us to validate the accuracy of spot estimates from radar track data. The results of comparing SMAP spot data with radar spot estimates are shown in Table 3. The table shows the number of cases where the SMAP spot agreed with the radar estimate ($S = R$) and where it disagreed ($S \neq R$). The "Single Samp." and "Multi. Samp." columns show the proportion of spot determinations based on a single position datum or an average of multiple positions; i.e. whether the position data were averaged for a stationary target or derived from a single sample for a moving target.

Table 3 Agreement between SMAP spot and radar estimate

	Cases	Single Samp.	Multi. Samp.
$S=R$	2,345 (90.3%)	1,396 (59.5%)	949 (40.5%)
$S\neq R$	252 (9.7%)	66 (26.2%)	186 (73.8%)
Total	2,597		

The spot estimated from radar track data agreed with the SMAP data in more than 90% of cases. Disagreements were further analysed by categorising them as follows:

ADJ The radar closest spot is adjacent to the SMAP spot.

PB The radar closest spot is near the likely pushback path from the SMAP spot.

TXY The transponder was switched on while the aircraft was taxiing to the runway.

OTH Other.

The numbers of disagreements by category are shown in Table 4. In the more than two thirds of cases the radar estimate of the closest initial spot is adjacent to the SMAP departure spot. For nearly a quarter of disagreements the radar-derived spot was a non-adjacent spot close to the pushback path. From Table 3 it appears that in cases of discrepancy between the radar estimate and SMAP spot information, the majority of radar spot determinations (more than 70%) are based on the initial position of a moving aircraft. It is therefore thought that in the majority of cases of disagreement the transponder was switched on while the aircraft was being pushed back, or during the time it was stationary while the tug was being disconnected, or just after the aircraft had started taxiing.

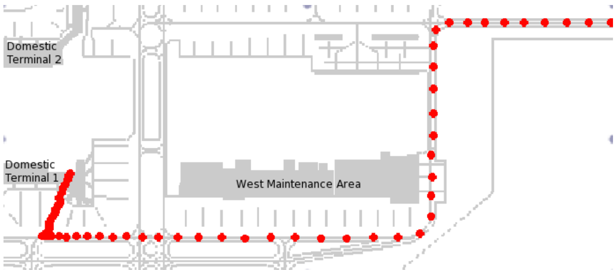
Table 4 Disagreement between SMAP spot and radar estimate

Category	Number
ADJ	170 (67.5%)
PB	56 (22.2%)
TXY	14 (5.6%)
OTH	12 (4.8%)
Total	252

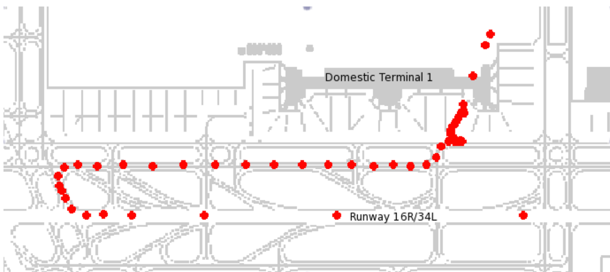
For the 'ADJ' cases, some spots appear to be more prone to misidentification of the adjacent spot from radar data than others; in particular it appears that radar data cannot be used to reliably discriminate between closely spaced spots that share a common number, e.g. 67, 67L and 67R.

In the 'TXY' cases (just under 6% of the total) the transponder was selected on while the aircraft was taxiing at some distance from the departure spot. The 'OTH' cases comprise various anomalies in the radar track data: for example apparent cases of the transponder being on before arrival at the spot and 'random' initial position samples. These cases accounted for just under 5% of spot discrepancies. Some examples showing radar track data corresponding to a few of these cases are shown in Figure 2.

For the 'N' apron, comparison of ODAP spot and the radar data showed only two agreements and 12 disagreements, indicating that radar estimates are not reliable for that area. A detailed analysis of the reasons was not carried out, but it has been observed that some aircraft do not park at a designated spot.



(a) Departure from Terminal 1 via runway 05



(b) Departure from Terminal 1 via runway 16R

Figure 2 Sample radar data from OTH cases

3.2.3 ODAP Spot Characteristics

Although SMAP spot information is more reliable than ODAP information, it is mostly available only for domestic airlines. We therefore look at the characteristics of ODAP spot information.

ODAP spot data agreed with the radar spot estimate in 87.3% of cases, so it appears fairly reliable. However, foreign carriers mainly use the International terminal but many spots adjacent to that terminal have L/R spots, which cannot be discriminated using radar data. If the distinction is not important, ignoring the 'L' and 'R' suffix can strengthen the validation of ODAP spot information by radar track data where SMAP data are not available.

While SMAP spot data are records of actual spot use, ODAP spot information is thought to be *planning* information. Discrepancies between the two might arise when an aircraft is planned to use a certain spot but another spot was in fact used.

3.3 Turnaround Times

We now report on a preliminary analysis of turnaround times computed from the AIBT and AOBT recorded by the SMAP system. A total of 7,423 turnaround times were analysed for three separate weeks in February, May and July 2011. For SMAP data availability reasons, the analysis is limited largely to spots used by domestic carriers. It can be considered reasonably complete for spots at the domestic terminals, while partial data exist for spots at the international terminal.

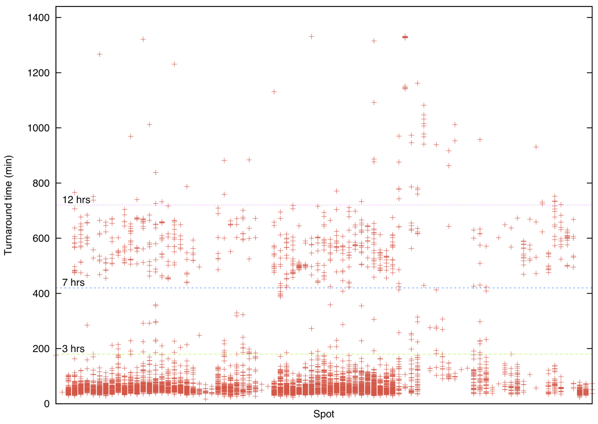


Figure 3 Turnaround times for each spot

The distribution of turnaround times for each spot is plotted in Figure 3. The vertical axis shows times in minutes up to 24 hours, with horizontal lines drawn at 3, 7 and 12 hours. Eight data points had values greater than 24 hours and are not shown. Turnaround times are grouped largely into two bands: less than 3 hours (approximately 90% of all times) and 7–12 hours (7%). Less than 1% of turnaround times lie between 3 and 7 hours.

3.3.1 Domestic Flights

We examined turnaround times for aircraft with a turnaround time of less than two hours that arrived from and then departed to an airport in Japan. There were 6,343 times analysed, with a minimum of 17 minutes. The median was 52 minutes and the mean was 56.3 minutes, with a standard deviation of 17.9 minutes. The mode was between 40 and 50 minutes.

Turnaround times were also analysed by aircraft type. Aircraft were divided into three categories: regional/commuter, narrowbody mainline and widebody mainline. The median and mean times for regional/commuter and narrowbody aircraft were shorter than for widebody aircraft, as would be expected from their relative passenger capacities (median turnaround times of 48, 49 and 55 minutes respectively for regional/commuter, narrow-body and widebody), but the difference is slight and its statistical significant was not tested.

3.3.2 International Flights

We also analysed turnaround times for flights that arrived from and then departed to a foreign airport. Due to the limited availability of SMAP data for international flights, only 61 turnaround times could be extracted. Of these, 57 were for a domestic carrier and the remaining four for various foreign carriers. Aircraft types were all widebody with the exception of a single narrowbody service to Seoul.

Over 70% of flights were turned around within three hours, with a minimum time of 90 minutes. All flights within the 90–120 minute bin were either arrivals from Seoul being turned around to Seoul, or arrivals from Honolulu being turned around to Honolulu. These data suggest that these flights are being operated practically as "shuttle" services.

4. Departure Spot Validation

Based on the spot data analysis, we devised the following method for automatically determining departure spot from SMAP, ODAP and radar data for creating simulation scenarios.

1. If SMAP spot exists, set the departure spot to the SMAP spot.
2. Otherwise compute the closest spot to the radar track initial position. If the distance from the closest spot is greater than 50 m the radar position is rejected.
3. If ODAP spot exists, compare it with the radar estimate computed in step (2), ignoring 'L' and 'R' suffixes. If they are the same, set the departure spot to the ODAP spot.
4. Otherwise leave the departure spot blank (to be determined by inspection of radar track or similar flights).

This method was applied to flights for three weeks in May, July and September 2011. Of 10,255 departures, the method failed to determine the spot in 393 cases, less than 4% of the total. Of these, 276 cases were for Domestic or Foreign carriers, so timetable information or comparison with the same flight number on other days may be used to determine the likely spot used.

5. Conclusions

The above findings are summarised below.

- SMAP information is a reliable indicator of departure spot used, but is largely available only for Japanese domestic airlines.
- ODAP spot information is available for the majority of airline departures, both foreign and domestic, and the majority of 'Other' category (mostly foreign general aviation) flights, but availability depends on the airline. ODAP spot information is mostly accurate but is thought to be derived from planning information and spot re-assignment for operational reasons can cause it to differ from the actual spot used. If only ODAP spot information is available, it may be validated with estimates from multilateration radar data.
- The spot estimated from radar track data is accurate in about 80% of cases. However, certain spots (the 'N' apron, spots with associated 'L' and 'R' spots) appear more likely than others to be misidentified. A major cause of misidentification is considered to be the activation of the aircraft transponder during pushback or taxiing.
- In the absence of SMAP and ODAP information, the spot can only be estimated from radar track data. Most of such cases are flights originating from the 'N' apron, where determination of spot from multilateration data is unreliable. However, these flights comprise only a small proportion (less than 3%) of departures.
- Of flights for which SMAP AOBT and AIBT data are available, 90% of flights are turned around within three hours, while 7% of flights have turnaround times of 7–12 hours. The former are considered as aircraft turning around between successive services, while the latter are considered as long-term or overnight parking.
- For domestic flights, the median turn-around time is 52 minutes and the mean is 56.3 minutes. Turnaround time appears to depend on aircraft size.
- For international flights, only a limited amount of data were available but over 70% were turned around within three hours. Aircraft turned around within 90–120 minutes were services to Seoul (a short haul destination) and Honolulu.

From this study, we devised a method that makes a "best guess" of the departure spot from available sources of information. The method fails in less than 4% of cases, and for the majority of these cases the spot can be estimated by referring to the spot used by the same timetabled flight on another day.

Further analysis of turnaround time will continue, and the results will be incorporated into our simulation model.

Acknowledgements

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References

[1] ブラウン マーク、青山 久枝、山田 泉、住谷 美登里：空港面交通管理のための羽田空港の駐機スポット情報に関する解析。IEICE Technical Report, SANE 2011-143.