Master Data Set for Aviation Safety Analysis

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In Korea, the Ministry of Land, Infrastructure, and Transportation has been developing a big-data platform for aviation safety management using national aviation data. Aviation data includes not only the track data but also data related to the aircraft, such as weather and flight plans. However, these data are managed by various stakeholders, and the integrated aviation data are not provided. Since there were no integrated aviation data that encompass various fields, many researchers have been forced to pre-process these separate data to analyze. Although the researchers integrated the data from different fields, it was hard to commonly use because only a few fields were integrated, or the used data were hard to be obtained. It is necessary to design an integrated database so the researchers can use the data that they need. This paper presents the master data set for aviation safety analysis and data integration using data from various fields that are independent but deeply related. As original sources, Automatic Dependent Surveillance-Broadcast, Korean Local Analysis and Prediction System, and Aeronautical Information Publication data were integrated to master data set.

Key Words: Master Data Set, Data Integration, Aviation Safety

1. Introduction

Since the Fourth Industrial Revolution, big data has been used in many fields. In aviation, International Civil Aviation Organization (ICAO) has been suggesting introducing a data-based safety management system.[1,2)] Federal Aviation Administration (FAA) developed the Aviation Safety Information Analysis and Sharing (ASIAS) system to integrate aviation data from most stakeholders in the United States and has been providing various services.[3,4)]

In Korea, the Ministry of Land, Infrastructure, and Transportation (MOLIT) has been developing a big-data platform for aviation safety management using national aviation data. However, there are currently no integrated aviation data in Korea, so there are many difficulties in research using data such as analysis of aviation safety events and warning signs. The aviation data are separately managed and analyzed by each stakeholder, such as the government and airlines, and it is hard to share their data.[5,6)]

This paper presents the schema of the Master Data Set that integrates aviation data and can be used in most aviation fields. It also describes the data integration process using data that can be easily obtained in public, not just provided by stakeholders. Section **2.** explains the necessity and uses of the master data set. Section **3.** briefly describes the master data set schema, data fields, and data integration of the original data. Section **4.** describes the sample master database integrated ADS-B, weather, and AIP data. Section **5.** concludes this paper.

2. Master Data Set

In a narrow sense, aviation data refers to 'track' or 'record' data that includes information such as position and attitude - Automatic Dependent Surveillance-Broadcast (ADS-B), Automated Radar Terminal Systems (ARTS), and Flight Record Data (FDR). However, many researchers use other types of data, not just the track data. For example, general track data such as ADS-B and ARTS provide speed information to ground speed. To analyze aircraft dynamics, airspeed should be used because the aircraft always be affected by the wind. Airspeed can be converted from ground speed using wind speed extracted from the weather data.[7)] For the aviation safety analysis, it is necessary to compare the aircraft track and air traffic control procedures and routes.[8,9)] Combining track data with data related to air traffic control such as Aeronautical Information Publication (AIP)[10)] can make this analysis easily performed.

The heterogeneous data such as Weather and AIP are structured so that the data format is suitable to use in each field. ADS-B and ARTS provide the same aircraft tracking information, but they have different data fields in detail. To utilize two or more data, it is necessary to understand the definition and standard of the data fields constituting each data and to transform and integrate them according to their purpose. Since detailed data such as FDR is hard to obtain because it may include sensitive data related to operators, many researchers had to obtain and integrate data independently. Sharing integrated data reduces unnecessary processes and enables efficient research.

The master data set presented in this paper integrates typical data used in aviation and contains most of the information necessary for all processes in aircraft operation. As shown in Fig. 1, when used as a server database, users can share the data provided by the master data set and use it for their purposes.

3. Data Integration

This section describes the process of integrating the original data sources to create master data set. Figure 2 shows the schema of the Master Data Set. As shown in Fig. 2, each data field may have its value (gray cells) or not (white cells). Depending on their characteristics, the data fields of the master data set can be classified into 7 categories. In this paper, 5 Categories related to data integration will be briefly explained, except 'Grid and Clusters' and 'Event Alerts'.

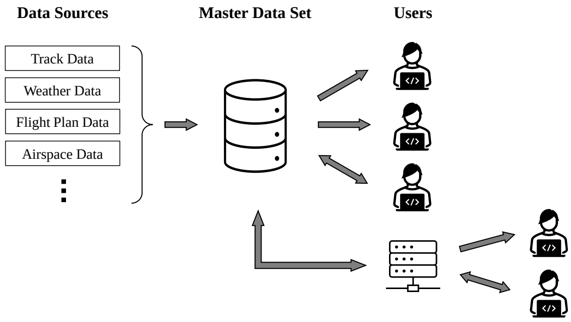

Fig. 1. Data sharing based on master data set

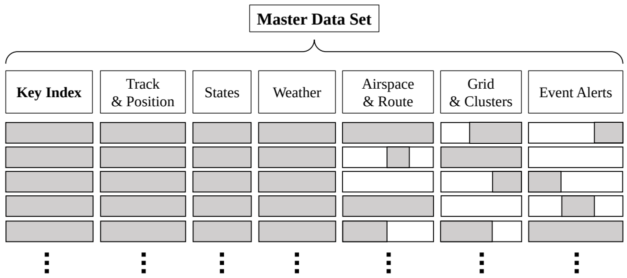

Fig. 2. Master data set schema

3.1. Key Index

The master data set should be able to provide data in units of one flight according to conditions. And the data for one flight should provide location over time and relevant details. All information in the master data set is sorted based on the key index, and the data of one flight is sorted based on the date and time among the key indexes. The data fields used as key indexes are shown in Table 1, where 'Id' must be a unique value of each flight.

Table 1. Data fields for aircraft key index

Data Field	Description	Unit
Id	Aircraft Unique Identification	
Callsign	Aircraft callsign	
Type	Aircraft type	
DateTime	Date and time at each point	

3.2. Aircraft Track and Position

Table 2 shows the data fields for flight track and position based on the tracking data. In this study, ADS-B data was used as an original track data source, and it can be replaced if there is more precise data such as ARTS, ASDE, and FDR. Because original data may be partially empty due to a large tracking interval or poor reception quality, the raw data should be supplemented with the processed data.

In this study, data supplement was performed in two methods. The first is a dynamic model-based simulation following a given track.[11,12] It requires the specifications such as aircraft type. Second, if there are no specifications, the track data is linearly interpolated. The groundspeed and ground track is computed using the aircraft position change.

3.3. Aircraft States

FDR data provides aircraft state information for detailed analysis such as aircraft attitude, weight, and thrust. However, track data such as ADS-B and ARTS do not include such states, the dynamic model was used to estimate the aircraft state data.[11,12] Table 3 summarizes the data fields that provide Aircraft State Information. Most data fields are calculated from the dynamic model, but the mass and pitch angle were estimated based on the data.

Table 2. Data fields for aircraft track and position

Data Field	Description	Unit
Latitude	Latitude from Raw or Processed data	deg
Longitude	Latitude from Raw or Processed data	deg
Altitude	Altitude from Raw or Processed data in MSL	ft
Vertical Rate	Vertical rate from Raw or Processed data	fpm
Ground speed	Ground speed from Raw or Processed data	knot
Course	Ground track from Raw or Processed data	deg
Altitude (FL)	Altitude in FL	
Altitude (AGL)	Altitude in AGL	ft
Travel Distance	Cumulative flight distance	m

Table 3. Data fields for aircraft states

Data Field	Description	Unit
Flight Path Angle	Aircraft flight path angle	deg
Roll	Aircraft roll angle	deg
Pitch	Aircraft pitch angle	deg
Yaw	Aircraft yaw angle	deg
TAS	True airspeed	knot
CAS	Calibrated airspeed	knot
IAS	Indicated airspeed	knot
Mass	Aircraft mass	kg
C_L	Lift coefficient	
C_D	Drag coefficient	
Lift	Lift force	N
Drag	Drag force	N
Thrust	Aircraft thrust	N

3.3.1. Initial Mass Estimation

Aircraft weight or mass is an important parameter. However, it is not easy to obtain, so the aircraft weight or mass should be estimated within a reasonable range. In this study, the initial mass of full flight from origin to destination was estimated using fuel consumption, empty mass (m_e), maximum takeoff mass ($MTOM$), and maximum payload mass ($m_{p_{max}}$) from Base of Aircraft Data (BADA).[12] Figure 3 shows the initial mass estimation algorithm. In Fig. 3, m_i and m_f are initial mass and final mass. m_{min} is minimum mass and it is equal to m_e. m_f, m_{f_c}, m_{f_r} are fuel mass, consumed fuel mass, and remained fuel mass. m_p is a payload mass and $\dot{m}_{avg}$ is average fuel consumption.

As shown in Fig. 3, estimation starts with $MTOM$ as an initial mass and the dynamic model computes the fuel consumption at every update. If the model computes that the drag is larger than thrust during simulation, the initial mass is reduced and estimation is restarted. If the m_f is smaller than m_e after the simulation, it is considered as not converging case, so it is impossible to estimate. When m_f is determined, m_{f_c} can be computed by subtracting m_f from m_i. The remained fuel mass m_{f_r} is assumed to amount of fuel that the aircraft can operate extra flight about 30 minutes. And m_f is a sum of m_{f_r} and m_{f_c}. The payload mass m_p is the minimum value between the maximum payload and the subtraction of m_e and m_f from $MTOM$. Through this rough estimation, the initial mass can be determined as a sum of m_e, m_p, and m_f.

If the initial mass is estimated, it is set to one of the initial states of the dynamic model so it can compute aircraft states. If estimation failed, data is linearly interpolated without other states.

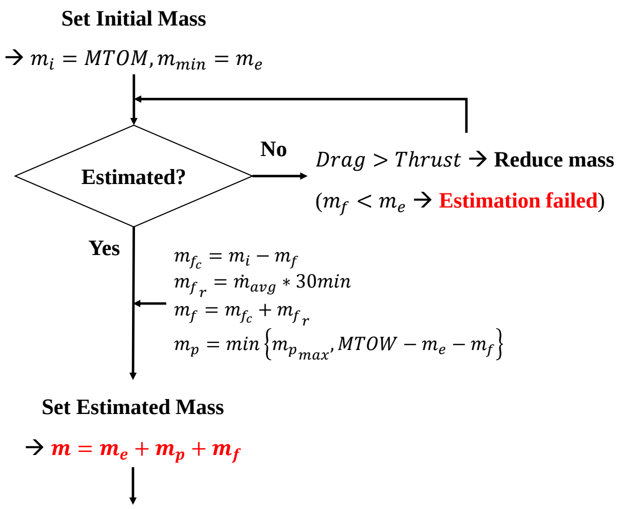

Fig. 3. Initial mass estimation algorithm

3.3.2. Attitudes and Wind Correction

The model used in this study is simpler than the 6-DOF model, but not all attitudes are calculated.[11] Considering the wind correction, roll and yaw angles are calculated based on ground speed, ground track, wind speed, and wind direction.[7] Pitch angle is conservatively estimated based on the flight path angle and lift curve slope calculated from the dynamic model.

3.4. Weather

Though using observed weather data is the most accurate, observation data is only provided for some regions and times. Since forecast data is often used instead of observation data in the weather field, Korean Local Analysis and Prediction System (KLAPS)[13] provided by the Korea Meteorological Administration were used in this study. Weather data fields should provide weather information including wind components at the location of the flight as shown in Table 4. Therefore, it is necessary to estimate the weather information at the corresponding track position based on the weather data.

The KLAPS provides the meteorological data with isobaric surfaces. And each grid point on the surface has the data such as wind components, geopotential heights, and temperature. However, the aircraft altitude is provided as MSL altitude, so the data needs to be converted between two standards to get the wind and atmospheric properties at the aircraft position.

In this study, the weather data on MSL altitude surfaces was generated from isobaric surface as shown in Fig. 4 and 5. Figure 5 shows the geopotential heights of each point on the same isobaric surfaces. As shown in Fig. 5, the altitudes of each grid point are different if the points have a same pressure. The wind,

Table 4. Data fields for weather

Data Field	Description	Unit
U Wind	Wind components at the aircraft position	knot
V Wind		
W Wind		
Wind Speed	Wind speed	knot
Wind Course	Wind track angle	deg
Pressure	Pressure at the aircraft position	Pa
Temperature	Temperature at the aircraft position	K
P0	Pressure on the surface	Pa
T0	Temperature on the surface	K

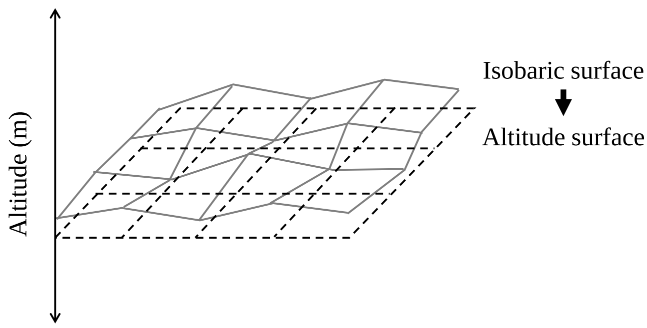

Fig. 4. Surface conversion from isobaric to altitude

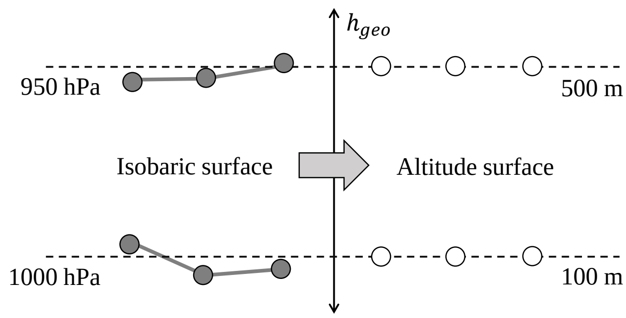

Fig. 5. Surface conversion from isobaric to altitude

pressure, and temperature data can be obtained by interpolation using altitude.

3.5. Airspace and Route

Table 5 shows the data fields for airspace and route information. These provide information on departure and arrival airports, passed airspaces, and actual routes of each flight to analyze efficiency and safety in air traffic management. The flight route can be represented as a set of nodes and links of airports or airways. If there are no historic records of flight plan, it can be estimated by comparing the flight tracks and route coordinates in AIP.[8,9]

Table 5. Data fields for airspace and routes

Data Field	Description	Unit
Airspace	Airspace id that flight is located	
Entry Node	Entry node id (Gate, Runway, Fix, etc.)	
Exit Node	Exit node id (Gate, Runway, Fix, etc.)	
Position	Flight position between entry and exit nodes	%
Procedure	Procedure that flight is following	
Vectoring	Vectoring by ATC	T/F

4. Integrated Database Example

The sample master database has been developed by integrating ADS-B from FlightAware,[14] KLAPS, and AIP data using MySQL. Figure 6 shows example of the summarized table of the total master database. Summarized table provides the flight list that includes key indexes, origin and destination airports, and the dates of departure and arrival so it is possible to search master database faster.

id	callsign	type	origin	destination	dep_date	arr_date
AAR8002-1551308700-schedule-0000:0	AAR8002	A320	RKPC	RKPK	2019-03-01	2019-03-01
AAR8002-1569645954-airline-0190:0	AAR8002	A320	RKPC	RKPK	2019-09-30	2019-09-30
AAR8230-1546125300-schedule-0000:0	AAR8230	A321	RKPC	RKTU	2018-12-31	2019-01-01
AAR8963-1551243900-schedule-0001:0	AAR8963	A321	RKSS	RKPC	2019-03-01	2019-03-01
ABL8190-1551248844-airline-0254:0	ABL8190	A320	RKPC	RKPK	2019-03-01	2019-03-01
ESR201-1551302400-schedule-0000:0	ESR201	B738	RKSS	RKPC	2019-03-01	2019-03-01

Fig. 6. Example flight list in master database

Figure 7 shows the aircraft tracks in the sample master database. The empty spaces in raw track data was filled by processed data as shown in Fig. 7, 8, and 9. In Fig. 9, the descent trajectory appears as a step due to the dynamic model, they can be replaced if the more accurate data exist.

id	datetime	lat_raw	lon_raw	alt_raw	gs_raw	vr_raw	crs_raw	lat_procd	lon_procd	alt_procd	gs_procd	vr_procd
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:46	37.5737	126.774	1150	165	2559	306	37.5737	126.774	1150	165	0
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:47	NULL	NULL	NULL	NULL	NULL	NULL	37.574154	126.773241	1191	163	2477
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:48	NULL	NULL	NULL	NULL	NULL	NULL	37.574615	126.772489	1233	163	2498
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:49	NULL	NULL	NULL	NULL	NULL	NULL	37.575081	126.771742	1275	163	2502
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:50	NULL	NULL	NULL	NULL	NULL	NULL	37.575551	126.770999	1316	163	2501
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:51	NULL	NULL	NULL	NULL	NULL	NULL	37.576024	126.770261	1358	163	2496
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:52	NULL	NULL	NULL	NULL	NULL	NULL	37.576501	126.769526	1399	163	2490
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:53	NULL	NULL	NULL	NULL	NULL	NULL	37.576982	126.768796	1441	163	2484
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:54	NULL	NULL	NULL	NULL	NULL	NULL	37.577467	126.768071	1482	163	2477
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:55	NULL	NULL	NULL	NULL	NULL	NULL	37.577958	126.767352	1523	162	2471
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:56	NULL	NULL	NULL	NULL	NULL	NULL	37.578454	126.76664	1564	162	2463
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:57	NULL	NULL	NULL	NULL	NULL	NULL	37.578957	126.765935	1605	162	2455
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:58	NULL	NULL	NULL	NULL	NULL	NULL	37.579467	126.76524	1646	162	2447
ESR201-1551302400-schedule-0000:0	2019-03-01 21:33:59	NULL	NULL	NULL	NULL	NULL	NULL	37.579987	126.764556	1687	162	2437
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:00	NULL	NULL	NULL	NULL	NULL	NULL	37.580518	126.763886	1727	162	2425
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:01	NULL	NULL	NULL	NULL	NULL	NULL	37.581065	126.763236	1767	162	2408
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:02	NULL	NULL	NULL	NULL	NULL	NULL	37.581575	126.76254	1807	162	2375
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:03	37.5825	126.762	1875	165	1969	308	37.582074	126.761828	1843	163	2147
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:04	NULL	NULL	NULL	NULL	NULL	NULL	37.582568	126.761113	1882	162	2382
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:05	NULL	NULL	NULL	NULL	NULL	NULL	37.583061	126.760398	1922	162	2408
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:06	NULL	NULL	NULL	NULL	NULL	NULL	37.583557	126.759685	1962	162	2404
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:07	NULL	NULL	NULL	NULL	NULL	NULL	37.584055	126.758975	2002	162	2396
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:08	NULL	NULL	NULL	NULL	NULL	NULL	37.584556	126.758271	2045	162	2564
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:09	NULL	NULL	NULL	NULL	NULL	NULL	37.585061	126.757572	2088	162	2562
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:10	NULL	NULL	NULL	NULL	NULL	NULL	37.58557	126.756879	2130	162	2554
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:11	NULL	NULL	NULL	NULL	NULL	NULL	37.586085	126.756192	2173	162	2546
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:12	NULL	NULL	NULL	NULL	NULL	NULL	37.586606	126.755513	2215	162	2538
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:13	NULL	NULL	NULL	NULL	NULL	NULL	37.587134	126.754843	2257	162	2529
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:14	NULL	NULL	NULL	NULL	NULL	NULL	37.587669	126.754183	2299	161	2519
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:15	NULL	NULL	NULL	NULL	NULL	NULL	37.588213	126.753536	2341	161	2509
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:16	NULL	NULL	NULL	NULL	NULL	NULL	37.588769	126.752905	2383	161	2496
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:17	NULL	NULL	NULL	NULL	NULL	NULL	37.589345	126.752288	2383	163	0
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:18	NULL	NULL	NULL	NULL	NULL	NULL	37.589879	126.751632	2423	163	2415
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:19	37.591	126.751	2400	164	2250	306	37.590407	126.75095	2461	165	2301
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:20	NULL	NULL	NULL	NULL	NULL	NULL	37.590931	126.750252	2503	166	2515
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:21	NULL	NULL	NULL	NULL	NULL	NULL	37.591456	126.749543	2546	168	2574
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:22	NULL	NULL	NULL	NULL	NULL	NULL	37.591984	126.748823	2590	169	2607
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:23	NULL	NULL	NULL	NULL	NULL	NULL	37.592514	126.748094	2633	171	2635
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:24	NULL	NULL	NULL	NULL	NULL	NULL	37.593049	126.747356	2678	173	2662
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:25	NULL	NULL	NULL	NULL	NULL	NULL	37.593588	126.746611	2723	174	2688
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:26	NULL	NULL	NULL	NULL	NULL	NULL	37.594132	126.745857	2768	176	2714
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:27	NULL	NULL	NULL	NULL	NULL	NULL	37.594681	126.745097	2814	178	2741
ESR201-1551302400-schedule-0000:0	2019-03-01 21:34:28	NULL	NULL	NULL	NULL	NULL	NULL	37.595236	126.744329	2860	179	2767

Fig. 7. Example of aircraft tracks in master database

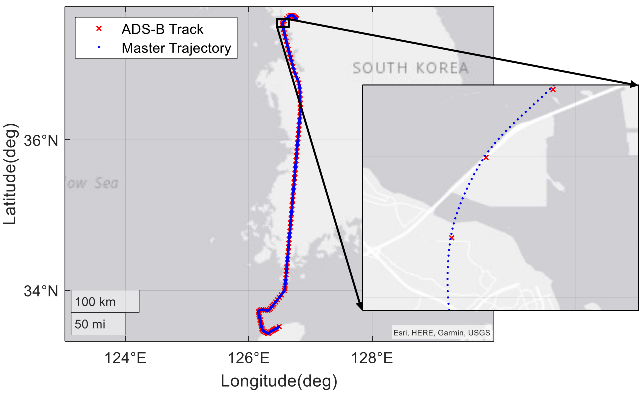

Fig. 8. Lateral track and trajectory

Figure 10 shows the aircraft states which were computed from the dynamic model. The initial mass was estimated in reasonable range as shown in Fig. 11.

Figure 12 shows data for the weather and airspace history. The TMA and sector that the aircraft positioned was recorded as the airspace information. And the wind component at the

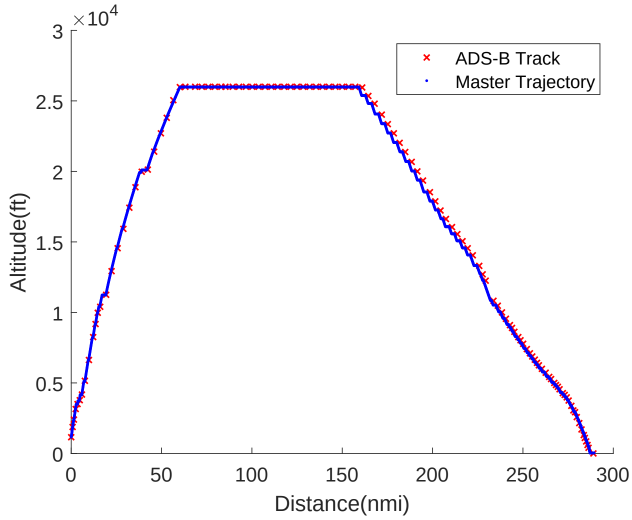

Fig. 9. Longitudinal track and trajectory

flt_path_angle	roll	pitch	yaw	tas	cas	ias	mass	cl	cd	lift	drag	thrust	throttle	flap	gear
0	0	0	306	163	159	NULL	65512	0	0	0	0	143467	NULL	Clean	NULL
9	8	17	307	163	159	NULL	65510	1	0	642432	45802	143467	NULL	Flap1	NULL
9	6	17	308	163	159	NULL	65508	1	0	642247	45855	143355	NULL	Flap1	NULL
9	4	17	308	162	159	NULL	65506	1	0	638819	45582	143242	NULL	Flap1	NULL
9	3	17	309	162	158	NULL	65504	1	0	636800	45451	143129	NULL	Flap1	NULL
9	3	17	309	162	158	NULL	65502	1	0	636224	45466	143016	NULL	Flap1	NULL
9	3	17	310	162	158	NULL	65500	1	0	636111	45527	142903	NULL	Flap1	NULL
9	4	17	310	162	158	NULL	65498	1	0	636194	45609	142791	NULL	Flap1	NULL
9	4	17	311	162	157	NULL	65496	1	0	636401	45703	142679	NULL	Flap1	NULL
9	5	17	311	162	157	NULL	65494	1	0	636721	45811	142567	NULL	Flap1	NULL
9	5	17	312	162	157	NULL	65493	1	0	637178	45933	142455	NULL	Flap1	NULL
8	6	17	312	162	157	NULL	65491	1	0	637828	46075	142344	NULL	Flap1	NULL
8	7	17	313	162	157	NULL	65489	1	0	638778	46250	142234	NULL	Flap1	NULL
8	9	17	314	162	156	NULL	65487	1	0	640228	46476	142123	NULL	Flap1	NULL
8	11	17	316	161	156	NULL	65485	1	0	642593	46790	142013	NULL	Flap1	NULL
8	15	17	317	161	156	NULL	65483	1	0	646930	47314	141904	NULL	Flap1	NULL
8	-30	17	313	161	156	NULL	65481	1	0	656706	48427	141795	NULL	Flap1	NULL
7	-10	18	312	161	155	NULL	65479	1	0	733852	57342	141688	NULL	Flap1	NULL
8	-3	17	312	161	155	NULL	65477	1	0	647157	47576	141591	NULL	Flap1	NULL
8	0	17	312	161	155	NULL	65475	1	0	636343	46513	141484	NULL	Flap1	NULL
8	2	17	312	161	155	NULL	65473	1	0	635321	46490	141376	NULL	Flap1	NULL
8	3	17	313	160	154	NULL	65472	1	0	635767	46623	141267	NULL	Flap1	NULL
9	4	17	313	160	154	NULL	65470	1	0	636312	39596	141159	NULL	Clean	NULL
9	4	18	314	160	154	NULL	65468	1	0	635757	39613	141044	NULL	Clean	NULL
9	5	18	314	160	154	NULL	65466	1	0	636181	39715	140928	NULL	Clean	NULL
9	6	18	315	160	153	NULL	65464	1	0	636700	39826	140813	NULL	Clean	NULL
9	6	18	316	160	153	NULL	65462	1	0	637319	39947	140699	NULL	Clean	NULL
9	7	18	316	159	153	NULL	65460	1	0	638117	40085	140584	NULL	Clean	NULL
9	8	18	317	159	152	NULL	65458	1	0	639215	40250	140471	NULL	Clean	NULL
9	9	18	319	159	152	NULL	65456	1	0	640809	40460	140357	NULL	Clean	NULL
9	11	18	320	159	152	NULL	65455	1	0	643279	40751	140244	NULL	Clean	NULL
0	14	9	322	159	152	NULL	65453	1	0	647443	41196	41196	NULL	Clean	NULL
8	-30	18	318	160	153	NULL	65452	1	0	662875	42637	140132	NULL	Clean	NULL
8	-13	18	316	162	154	NULL	65450	1	0	733163	49063	140023	NULL	Clean	NULL
9	-6	17	315	163	156	NULL	65449	1	0	651903	41102	139920	NULL	Clean	NULL
9	-3	17	315	165	157	NULL	65447	1	0	638650	39722	139807	NULL	Clean	NULL
9	-2	17	315	166	158	NULL	65445	1	0	635604	39252	139691	NULL	Clean	NULL
9	-1	17	315	168	160	NULL	65443	1	0	634747	38980	139574	NULL	Clean	NULL
9	-1	17	315	169	161	NULL	65441	1	0	634460	38766	139455	NULL	Clean	NULL
9	0	16	315	171	162	NULL	65439	1	0	634343	38577	139336	NULL	Clean	NULL
9	0	16	315	172	164	NULL	65437	1	0	634290	38404	139215	NULL	Clean	NULL
9	1	16	315	174	165	NULL	65435	1	0	634269	38244	139093	NULL	Clean	NULL
9	1	16	315	176	166	NULL	65433	1	0	634276	38097	138970	NULL	Clean	NULL

Fig. 10. Example of aircraft states in master database

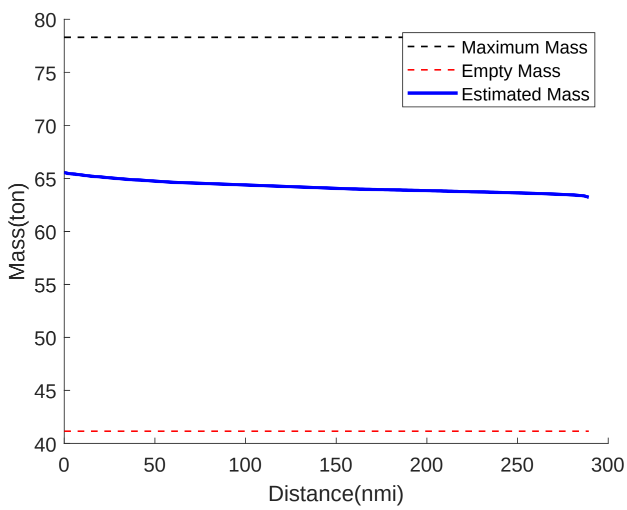

Fig. 11. Estimated mass change

aircraft position was extracted, the airspeed and attitudes were computed as shown in Fig. 10. Figure 13 shows the groundspeed, airspeed, and windspeed vectors at the aircraft positions.

u_wind	v_wind	w_wind	wind	crs_wind	pressure	temperature	pressure_surf	temperature_surf	airspace
-2	1	0	2	291	98005	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	291	98005	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	290	97850	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	290	97693	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	289	97535	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	289	97378	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	288	97221	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	2	287	97064	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	3	287	96908	274	102344	273	T01 (Seoul)/Incheon North
-2	1	0	3	286	96752	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	286	96597	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	286	96442	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	285	96288	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	284	96135	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	282	95991	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	280	95848	274	102344	273	T01 (Seoul)/Incheon North
-3	1	0	3	279	95705	274	102344	273	T01 (Seoul)/Incheon North
-4	0	0	4	277	95565	274	102344	273	T01 (Seoul)/Incheon North
-4	0	0	4	276	95438	274	102344	273	T01 (Seoul)/Incheon North
-4	0	0	4	275	95297	274	102344	273	T01 (Seoul)/Incheon North
-4	0	0	4	274	95155	274	102344	273	T01 (Seoul)/Incheon North
-5	0	0	5	273	95013	274	102344	273	T01 (Seoul)/Incheon North
-5	0	0	5	272	94871	274	102344	273	T01 (Seoul)/Incheon North
-5	0	0	5	271	94719	274	102344	273	T01 (Seoul)/Incheon North
-5	0	0	5	270	94568	274	102344	273	T01 (Seoul)/Incheon North
-5	-0	0	5	269	94417	274	102344	273	T01 (Seoul)/Incheon North
-6	-0	0	6	269	94266	274	102344	273	T01 (Seoul)/Incheon North
-6	-0	0	6	268	94116	274	102344	273	T01 (Seoul)/Incheon North
-6	-0	0	6	268	93967	274	102344	273	Incheon North/T01 (Seoul)
-6	-0	0	6	267	93818	274	102344	273	Incheon North/T01 (Seoul)
-7	-0	0	7	266	93670	274	102344	273	T01 (Seoul)/Incheon North
-7	-0	0	7	266	93522	274	102344	273	T01 (Seoul)/Incheon North
-7	-0	0	7	266	93522	274	102344	273	Incheon North/T01 (Seoul)
-7	-1	0	7	266	93380	274	102344	273	T01 (Seoul)/Incheon North
-7	-1	0	7	265	93243	274	102344	273	T01 (Seoul)/Incheon North
-8	-1	0	8	265	93095	274	102344	273	Incheon North/T01 (Seoul)
-8	-1	0	8	264	92943	274	102344	273	T01 (Seoul)/Incheon North
-8	-1	0	8	264	92789	274	102344	273	Incheon North/T01 (Seoul)
-8	-1	0	8	264	92633	274	102344	273	Incheon North/T01 (Seoul)
-9	-1	0	9	263	92475	274	102344	273	T01 (Seoul)/Incheon North
-9	-1	0	9	263	92317	274	102344	273	T01 (Seoul)/Incheon North
-9	-1	0	9	263	92156	274	102344	273	T01 (Seoul)/Incheon North
-9	-1	0	9	262	91994	274	102344	273	Incheon North/T01 (Seoul)

Fig. 12. Example of weather and airspace history in master database

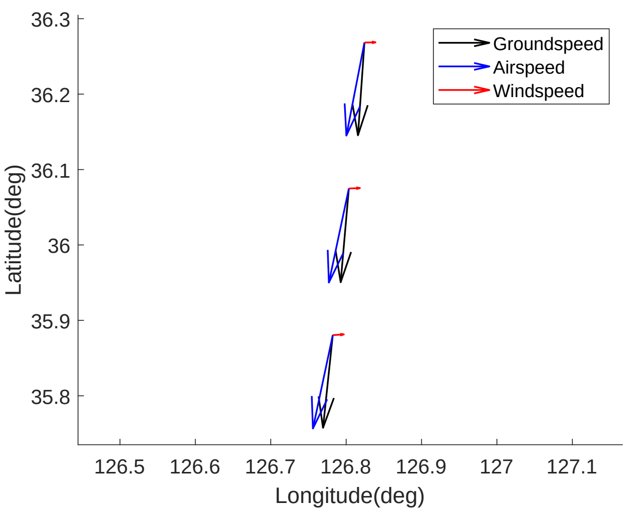

Fig. 13. Groundspeed, airspeed, and windspeed at each point

5. Conclusion

This paper presents a master data set that provides most of the information in the entire flight history and data integration of ADS-B, Weather, and AIP that can be easily obtained but have different formats and characteristics. The master data set can be used for various fields in aviation and can be expanded according to the data and research purpose. If it is used as a database of data sharing platform, users can share the integrated data so the master data set can reduce individual data integration processes. The master database is being updated using integration of the ADS-B, KLAPS, and AIP in 2019. Currently, some data fields are empty, and filling the empty fields is going on progress. In addition, to use for the analysis of safety events and precursors, improving the accuracy and simplifying data fusion is a major research goal in the future.

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