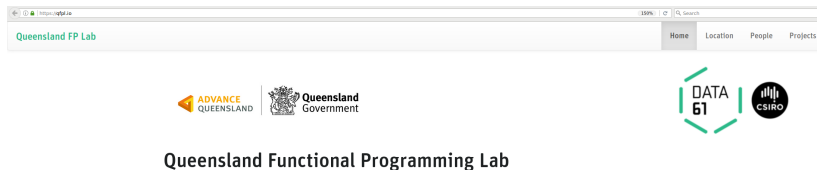
A yellow and white biplane with the registration "VH-YOW" is parked on a tarmac. The aircraft has a high-wing configuration and a tail boom. In the background, there is a brick building and some trees.

Functional Programming in Aviation

YOW!, Sydney, December 2017

Tony Morris

<http://qfpl.io/>



Questions I have been asked at YOW! 2017

FAQ

- **How can I be notified of upcoming FP courses?**
 - Subscribe to this mailing list
<http://notify.qfpl.io/>
 - Sign up to YOW! conference notifications
- **Do you do non-introductory FP courses?**
Coming in 2018. Sign up to notifications.
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 - Yes
 - No really, yes
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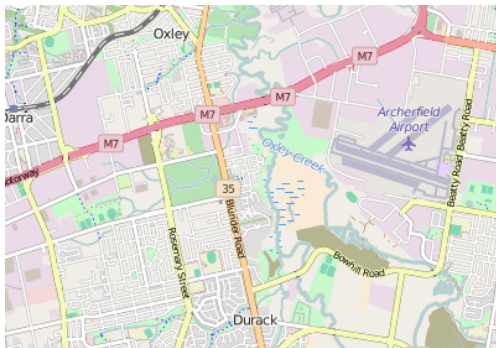
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Why aviation?

My house is near this airport



and I'd see this on my way home



This is me on my way home



In November 2015, I did this



flight school archerfield airport

Google Search

I'm Feeling Lucky

A domestic argument ensued

My lovely wife Amanda was like



A compromise was reached

and I was like



The argument was over

and Amanda was like



There are (loosely) four levels of pilot licence

1 RPL

- MTOW \leq 1500kg
- no navigation beyond 25nm (46km) from departure point
- day time, VFR only
- class 1 or 2 aviation medical for >1 PAX

2 PPL

- MTOW \leq 5700kg
- can navigate
- no commercial ops
- class 1 or 2 aviation medical for >1 PAX

3 CPL

- commercial ops
- class 1 aviation medical

4 ATPL

- \geq 1500 hours for aeroplane category
- \geq 1000 hours for helicopter category

Civil Aviation in Australia

- Federally regulated by Civil Aviation Safety Authority (CASA).
- Services, such as weather reporting, provided by Airservices Australia.

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Civil Aviation in Australia

and we don't want this to happen



Rail gauge in Australia

From Wikipedia, the free encyclopedia

Rail gauges in Australia display significant variations, which has presented an extremely difficult problem for rail transport on the Australian continent for over 150 years. As of 2014, there is 11,801 kilometres (7,333 mi) of [narrow-gauge railways](#), 17,381 kilometres (10,800 mi) of [standard gauge](#) railways and 3,221 kilometres (2,001 mi) of [broad gauge](#) railways.

Civil Aviation internationally

so these also exist

- International Air Services Commission (IASC).
- International Civil Aviation Organisation (ICAO).

Civil Aviation internationally

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Australian aviation legislation

- Civil Aviation Act 1988 (CAA1988).
- Under CAA1988, is Civil Aviation Safety Regulations 1998 (CASR1998).
- There are also Civil Aviation Orders (CAO).
- and Civil Aviation Advisory Publications (CAAP).

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CASR1998 REG 61.345 (*pilot logbooks*)

61.345 Personal logbooks—pilots

- (1) A person who holds a pilot licence, or a certificate of validation of an overseas flight crew licence that is equivalent to a pilot licence, commits an offence if the person does not keep a personal logbook in accordance with this regulation.
Penalty: 50 penalty units.
- (2) The person must record his or her full name and date of birth in the person's logbook.
- (3) The person must, as soon as practicable after completing each flight, record the following information in the person's logbook for the flight:
 - (a) the date the flight began;
 - (b) the type of aircraft;
 - (c) whether it was a single-engine or multi-engine aircraft;
 - (d) the aircraft's nationality and registration marks;
 - (e) the take-off and landing points for the flight, and for each segment of the flight;
 - (f) the flight time (if any) flown in each of the following capacities:
 - (i) pilot in command;
 - (ii) co-pilot;
 - (iii) pilot in command under supervision;
 - (iv) pilot receiving flight training;
 - (g) if the person is a flight instructor—any flight time spent exercising the privileges of his or her flight instructor rating;
 - (h) if the person is a flight examiner—any flight time spent exercising the privileges of his or her flight examiner rating;
 - (i) whether the flight was by day or night, or both;
 - (j) any instrument flight time;
 - (k) whether the person conducted an instrument approach operation and, if so, the type of instrument approach procedure.
- (4) The person must, as soon as practicable after completing each simulated flight in a flight simulation training device, record the following information in the person's logbook for the simulated flight:
 - (a) the date the simulated flight began;
 - (b) the type of aircraft represented by the device;
 - (c) the simulated flight time (if any) performed in each of the following capacities:
 - (i) pilot in command;
 - (ii) co-pilot;
 - (iii) pilot in command under supervision;
 - (iv) pilot receiving flight training;
 - (d) if the person is a flight instructor or simulator instructor—any time spent exercising the privileges of his or her instructor rating;
 - (e) whether the flight was conducted in simulated day or night conditions, or both;
 - (f) a description of the simulated flight activity.

Pilot Logbooks

Here is a typical pilot logbook

The image shows an open pilot logbook. The left page is a summary page with fields for aircraft, engine, and totals. The right page is a detailed flight log with columns for time, fuel, and other metrics.

Left Page Summary:

FLIGHT NO.	DATE	TIME	FUEL	ALTITUDE	TYPE	REMARKS
1	10/10/10	10:00	100	1000	100	100
2	11/10/10	11:00	110	1100	110	110
3	12/10/10	12:00	120	1200	120	120
4	13/10/10	13:00	130	1300	130	130
5	14/10/10	14:00	140	1400	140	140
6	15/10/10	15:00	150	1500	150	150
7	16/10/10	16:00	160	1600	160	160
8	17/10/10	17:00	170	1700	170	170
9	18/10/10	18:00	180	1800	180	180
10	19/10/10	19:00	190	1900	190	190
11	20/10/10	20:00	200	2000	200	200
12	21/10/10	21:00	210	2100	210	210
13	22/10/10	22:00	220	2200	220	220
14	23/10/10	23:00	230	2300	230	230
15	24/10/10	24:00	240	2400	240	240
16	25/10/10	25:00	250	2500	250	250
17	26/10/10	26:00	260	2600	260	260
18	27/10/10	27:00	270	2700	270	270
19	28/10/10	28:00	280	2800	280	280
20	29/10/10	29:00	290	2900	290	290
21	30/10/10	30:00	300	3000	300	300
22	31/10/10	31:00	310	3100	310	310
23	01/11/10	01:00	320	3200	320	320
24	02/11/10	02:00	330	3300	330	330
25	03/11/10	03:00	340	3400	340	340
26	04/11/10	04:00	350	3500	350	350
27	05/11/10	05:00	360	3600	360	360
28	06/11/10	06:00	370	3700	370	370
29	07/11/10	07:00	380	3800	380	380
30	08/11/10	08:00	390	3900	390	390
31	09/11/10	09:00	400	4000	400	400
32	10/11/10	10:00	410	4100	410	410
33	11/11/10	11:00	420	4200	420	420
34	12/11/10	12:00	430	4300	430	430
35	13/11/10	13:00	440	4400	440	440
36	14/11/10	14:00	450	4500	450	450
37	15/11/10	15:00	460	4600	460	460
38	16/11/10	16:00	470	4700	470	470
39	17/11/10	17:00	480	4800	480	480
40	18/11/10	18:00	490	4900	490	490
41	19/11/10	19:00	500	5000	500	500
42	20/11/10	20:00	510	5100	510	510
43	21/11/10	21:00	520	5200	520	520
44	22/11/10	22:00	530	5300	530	530
45	23/11/10	23:00	540	5400	540	540
46	24/11/10	24:00	550	5500	550	550
47	25/11/10	25:00	560	5600	560	560
48	26/11/10	26:00	570	5700	570	570
49	27/11/10	27:00	580	5800	580	580
50	28/11/10	28:00	590	5900	590	590
51	29/11/10	29:00	600	6000	600	600
52	30/11/10	30:00	610	6100	610	610
53	01/12/10	01:00	620	6200	620	620
54	02/12/10	02:00	630	6300	630	630
55	03/12/10	03:00	640	6400	640	640
56	04/12/10	04:00	650	6500	650	650
57	05/12/10	05:00	660	6600	660	660
58	06/12/10	06:00	670	6700	670	670
59	07/12/10	07:00	680	6800	680	680
60	08/12/10	08:00	690	6900	690	690
61	09/12/10	09:00	700	7000	700	700
62	10/12/10	10:00	710	7100	710	710
63	11/12/10	11:00	720	7200	720	720
64	12/12/10	12:00	730	7300	730	730
65	13/12/10	13:00	740	7400	740	740
66	14/12/10	14:00	750	7500	750	750
67	15/12/10	15:00	760	7600	760	760
68	16/12/10	16:00	770	7700	770	770
69	17/12/10	17:00	780	7800	780	780
70	18/12/10	18:00	790	7900	790	790
71	19/12/10	19:00	800	8000	800	800
72	20/12/10	20:00	810	8100	810	810
73	21/12/10	21:00	820	8200	820	820
74	22/12/10	22:00	830	8300	830	830
75	23/12/10	23:00	840	8400	840	840
76	24/12/10	24:00	850	8500	850	850
77	25/12/10	25:00	860	8600	860	860
78	26/12/10	26:00	870	8700	870	870
79	27/12/10	27:00	880	8800	880	880
80	28/12/10	28:00	890	8900	890	890
81	29/12/10	29:00	900	9000	900	900
82	30/12/10	30:00	910	9100	910	910
83	31/12/10	31:00	920	9200	920	920
84	01/01/11	01:00	930	9300	930	930
85	02/01/11	02:00	940	9400	940	940
86	03/01/11	03:00	950	9500	950	950
87	04/01/11	04:00	960	9600	960	960
88	05/01/11	05:00	970	9700	970	970
89	06/01/11	06:00	980	9800	980	980
90	07/01/11	07:00	990	9900	990	990
91	08/01/11	08:00	1000	10000	1000	1000
92	09/01/11	09:00	1010	10100	1010	1010
93	10/01/11	10:00	1020	10200	1020	1020
94	11/01/11	11:00	1030	10300	1030	1030
95	12/01/11	12:00	1040	10400	1040	1040
96	13/01/11	13:00	1050	10500	1050	1050
97	14/01/11	14:00	1060	10600	1060	1060
98	15/01/11	15:00	1070	10700	1070	1070
99	16/01/11	16:00	1080	10800	1080	1080
100	17/01/11	17:00	1090	10900	1090	1090
101	18/01/11	18:00	1100	11000	1100	1100
102	19/01/11	19:00	1110	11100	1110	1110
103	20/01/11	20:00	1120	11200	1120	1120
104	21/01/11	21:00	1130	11300	1130	1130
105	22/01/11	22:00	1140	11400	1140	1140
106	23/01/11	23:00	1150	11500	1150	1150
107	24/01/11	24:00	1160	11600	1160	1160
108	25/01/11	25:00	1170	11700	1170	1170
109	26/01/11	26:00	1180	11800	1180	1180
110	27/01/11	27:00	1190	11900	1190	1190
111	28/01/11	28:00	1200	12000	1200	1200
112	29/01/11	29:00	1210	12100	1210	1210
113	30/01/11	30:00	1220	12200	1220	1220
114	31/01/11	31:00	1230	12300	1230	1230
115	01/02/11	01:00	1240	12400	1240	1240
116	02/02/11	02:00	1250	12500	1250	1250
117	03/02/11	03:00	1260	12600	1260	1260
118	04/02/11	04:00	1270	12700	1270	1270
119	05/02/11	05:00	1280	12800	1280	1280
120	06/02/11	06:00	1290	12900	1290	1290
121	07/02/11	07:00	1300	13000	1300	1300
122	08/02/11	08:00	1310	13100	1310	1310
123	09/02/11	09:00	1320	13200	1320	1320
124	10/02/11	10:00	1330	13300	1330	1330
125	11/02/11	11:00	1340	13400	1340	1340
126	12/02/11	12:00	1350	13500	1350	1350
127	13/02/11	13:00	1360	13600	1360	1360
128	14/02/11	14:00	1370	13700	1370	1370
129	15/02/11	15:00	1380	13800	1380	1380
130	16/02/11	16:00	1390	13900	1390	1390
131	17/02/11	17:00	1400	14000	1400	1400
132	18/02/11	18:00	1410	14100	1410	1410
133	19/02/11	19:00	1420	14200	1420	1420
134	20/02/11	20:00	1430	14300	1430	1430
135	21/02/11	21:00	1440	14400	1440	1440
136	22/02/11	22:00	1450	14500	1450	1450
137	23/02/11	23:00	1460	14600	1460	1460
138	24/02/11	24:00	1470	14700	1470	1470
139	25/02/11	25:00	1480	14800	1480	1480
140	26/02/11	26:00	1490	14900	1490	1490
141	27/02/11	27:00	1500	15000	1500	1500
142	28/02/11	28:00	1510	15100	1510	1510
143	29/02/11	29:00	1520	15200	1520	1520
144	01/03/11	01:00	1530	15300	1530	1530
145	02/03/11	02:00	1540	15400	1540	1540
146	03/03/11	03:00	1550	15500	1550	1550
147	04/03/11	04:00	1560	15600	1560	1560
148	05/03/11	05:00	1570	15700	1570	1570
149	06/03/11	06:00	1580	15800	1580	1580
150	07/03/11	07:00	1590	15900	1590	1590
151	08/03/11	08:00	1600	16000	1600	1600
152	09/03/11	09:00	1610	16100	1610	1610
153	10/03/11	10:00	1620	16200	1620	1620
154	11/03/11	11:00	1630	16300	1630	1630
155	12/03/11	12:00	1640	16400	1640	1640
156	13/03/11	13:00	1650	16500	1650	1650
157	14/03/11	14:00	1660	16600	1660	1660
158	15/03/11	15:00	1670	16700	1670	1670
159	16/03/11	16:00	1680	16800	1680	1680
160	17/03/11	17:00	1690	16900	1690	1690
161	18/03/11	18:00	1700	17000	1700	1700
162	19/03/11	19:00	1710	17100	1710	1710
163	20/03/11	20:00	1720	17200	1720	1720
164	21/03/11	21:00	1730	17300	1730	1730
165	22/03/11	22:00	1740	17400	1740	1740
166	23/03/11	23:00	1750	17500	1750	1750
167	24/03/11	24:00	1760	17600	1760	1760
168	25/03/11	25:00	1770	17700	1770	1770
169	26/03/11	26:00	1780	17800	1780	1780
170	27/03/11	27:00	1790	17900	1790	1790
171	28/03/11	28:00	1800	18000	1800	1800
172	29/03/11	29:00	1810	18100	1810	1810
173	30/03/11	30:00	1820	18200	1820	1820
174	31/03/11	31:00	1830	18300	1830	1830
175	01/04/11	01:00	1840	1840		

CASR1998 REG 61.345 (*pilot logbooks*)

Are electronic logbooks OK?

Yes. CASR1998 REG 61.365(3)

CIVIL AVIATION SAFETY REGULATIONS 1998 - REG 61.365

Production of personal logbooks

(1) CASA may direct the holder of a flight crew licence or certificate of validation to produce the holder's personal logbook for inspection by CASA.

(2) The holder of a flight crew licence or certificate of validation commits an offence if:

- (a) CASA directs the holder to produce his or her personal logbook under subregulation (1); and
- (b) the holder does not produce an up to date version of the personal logbook within 7 days after the day the direction is given.

Penalty: 50 penalty units.

(3) If the holder's personal logbook is kept in electronic form, a requirement to produce the logbook is met if:

- (a) the holder produces a printed copy of the logbook; and
- (b) each page is certified by the holder as a true copy of the logbook records set out on the page.

Introducing the pilot logbook cottage industry

What is the best digital logbook software or website available? (self.flying)

submitted 1 year ago by Dasgerman1984 [CPL](#)

Trying to go digital on a budget. What is everyone using?

Introducing the pilot logbook cottage industry

Excel?

An Excel spreadsheet I made. Free. Coupled with dropbox, works well.

Free copies upon request.

Introducing the pilot logbook cottage industry

Google spreadsheet?

I used google sheets from the get go but Logten is pretty sexy.
It may be overqualified for my needs right now but I won't turn back.

Introducing the pilot logbook cottage industry

proprietary logbook software?

I switched from a pre-subscription version of LogTen Pro to Foreflight's offering. I still keep a paper logbook, and am only a private, but in my opinion ForeFlight needs a few more features to be competitive. It does just fine for basic logging, it's the reporting side I'd like to see expanded, which they are working on.

Introducing the pilot logbook cottage industry

I love proprietary software!

I personally use Log Ten Pro X! So far it has been great.

Introducing the pilot logbook cottage industry

I hate proprietary software when it doesn't work

Hated LogTenPro because of the cost and issues with syncing.

Introducing the pilot logbook cottage industry

I hate proprietary software when I cross the date line

We really hate it when our software is not up to snuff. We guessed you might come from New Zealand and we tried to add a flight from New Zealand to Tahiti, crossing the international date line.

Introducing the pilot logbook cottage industry

umm where's my logbook gone?



Anyone else use Google Sheets as their logbook? (self.thyng)

submitted 5 hours ago by [Epic_Marsupial](#) [PPL IR KPWA](#)

I've been doing this for about a year now. I can access it on all my devices and it saves automatically, plus it's free! Anyone else tried using it? It's a great solution in my opinion and I'd recommend it to anyone wanting an internet backup.

16 comments share save hide give gold report

all 16 comments

sorted by: [best](#) ▼



save

[content policy](#) [formatting help](#)

[-] [chriscic](#) [PPL](#) 9 points 5 hours ago

It's free right up until the moment you accidentally delete it, and then discover Google Drive didn't automatically keep backup/shadow copies.

Ask me how I know.

01 August 2016

A responsible, CASR1998 REG 61.x compliant pilot uses

- Haskell data type (sums and products) for logbook.
- Lenses, Prisms and Traversals for querying and reporting.
- Pilot logbook zipper for navigating a logbook.
- A pretty-printer to meet CASR1998 REG 61.365 requirements.
- Revision control (git) for mitigating data loss.
- Publishes open-source logbook libraries as a good citizen.

lenses? zippers?

- what is a lens?
- prism?
- zipper?
- WHAT?

Here is the problem

- We all know and agree that immutable objects have significant advantages for our code.
- This idea has been known since the 1930s as: Functional Programming.

Here is the problem

- but a naïve effort toward achieving this thesis results in several, significant practical problems.
- and we are somewhat aware of these problems.

Pilot logbook

For example

given a logbook...

- that has an aviator...
- that has an ARN...
- that has 0 or many digits...

find the first digit that is even and, if it exists, add 1 to it

Logbook.java

Modify: Find the first digit that is even and, if it exists, add 1 to it

```
λ> :t over (singular
  (
    logbook .
    logbookaviator .
    arn .
    traverse .
    filtered digiteven
  )
)
successor
Logbook -> Logbook
```

Query: Aircraft from all flights

```
λ> :t mylogbook ^..  
    logbook .  
    logbookentries .  
    _Wrapped .  
    folded .  
    _AircraftFlightEntry .  
    flightaircraft  
[Aircraft]
```


Query: Find first flight in aircraft registration VH-VVO

```
λ> :t findOf
  ( logbook .
    logbookentries .
    _Wrapped .
    folded .
    _AircraftFlightEntry)
  ( elemOf
    (
      flightaircraft .
      aircraftRegistration)
    "VH-VVO")
mylogbook
Maybe AircraftFlight
```

Query: Total day hours as pilot in-command

```
λ> foldOf
  ( logbook .
    logbookentries .
    _Wrapped .
    folded .
    _AircraftFlightEntry .
    filtered
      (elemOf (command . _InCommand) ()) .
    daynight .
    dayDayNight
  )
  mylogbook
TimeAmount {_hours = 4, _tenthofhour = 8}
```

Print the entire logbook to a single, printable HTML web page
CASR1998 REG 61.365

```
λ> :t htmlLogbook mylogbook  
Html ()
```

<http://logbook.aviation.tmorris.net/>

Query of arbitrary obtuseness

All flights where, if the departure and arrival date is the same day (UTC), and that date-of-month is a multiple of 7, unless either there was an intermediate flight path point of YSCN, or the time the logbook owner was PiC for the first three legs of the flight, is between 2.0 hours and the total sum of hours of dual flight in aircraft registered VH-AFR.

What is the goal?

- The effort required to perform a query or update is directly proportional to the sophistication of that operation.
- Counting, querying, searching, updating, filtering, tabulating, transposing, intercalating, grouping, partitioning, indexing, unioning, intersecting on data in a pilot logbook is not only physically laborious, but prone to error.
- Yet this procedure is executed manually every day at airports.

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Aeronautical Data and Information

What is CASR1998 REG 175 about?

CIVIL AVIATION SAFETY REGULATIONS 1998 - REG 175.005

What Part 175 is about

- (1) This Part establishes standards and requirements for the quality and integrity of data and information used in air navigation.
- (2) Subpart 175.B establishes standards and requirements for AIS providers—persons responsible for the publication of aeronautical data and aeronautical information in the Integrated Aeronautical Information Package and on aeronautical charts.
- (3) Subpart 175.C establishes standards and requirements for data service providers—persons authorised to publish aeronautical data, aeronautical information or aeronautical charts, or to supply aeronautical data, that pilots may use as an alternative to the Integrated Aeronautical Information Package and aeronautical charts published by AIS providers.
- (4) Subpart 175.D sets out requirements for aeronautical data originators—persons responsible for providing aeronautical data and aeronautical information to AIS providers for publication in the Integrated Aeronautical Information Package and on aeronautical charts.
- (5) Subpart 175.E contains powers that can be used to gather data about objects and structures that affect aviation safety.

Note: The data gathered under Subpart 175.E will be used in air navigation applications, including the following:

- (a) the design of terminal instrument flight procedures;
- (b) the calculation of lowest safe altitudes;
- (c) aircraft operating limitations analysis;
- (d) minimum safe altitude warning systems;
- (e) the publication of visual navigation charts.

“(e) the publication of visual navigation charts.”

CAR1988 REG 233(1)(h) *moved to CASR1998 REG 175*

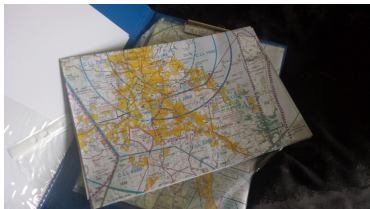
CAR1988 REG 233(1)(h)

The pilot in command of an aircraft must not commence a flight if he or she has not received evidence, and taken such action as is necessary to ensure, that:

...

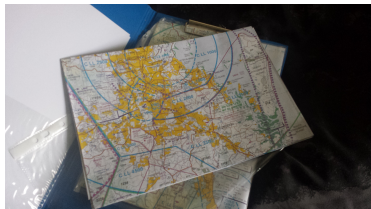
(h) the aeronautical data and aeronautical information mentioned in subregulation (1A) is carried in the aircraft and is readily accessible to the flight crew.

This is a Brisbane Visual Terminal Chart (VTC)



- It unfolds out to 500mm x 1000mm.
- Updated every 3 months (approx).

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Under CAR1988 REG 133(1)(h)

- These charts are required on every flight.
- Reading them during flight is physically impractical.
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Surely these exist in electronic format?

Why yes, they do.

but

AIS providers—publication of aeronautical charts relating to areas etc. outside authority

(1) This regulation applies if an AIS provider publishes an aeronautical chart that includes aeronautical data or aeronautical information that relates to an area, aerodrome, airspace or ATS route not covered by the provider's certificate.

No problem.
Let's use approved electronic AIS aeronautical charts.

but

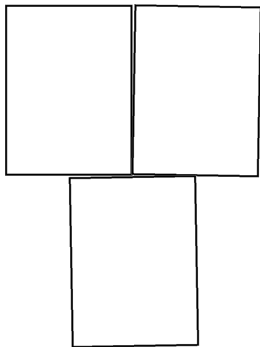
the paper charts are the authoritative, approved data source.

CASR1998 REG 175.145(1)

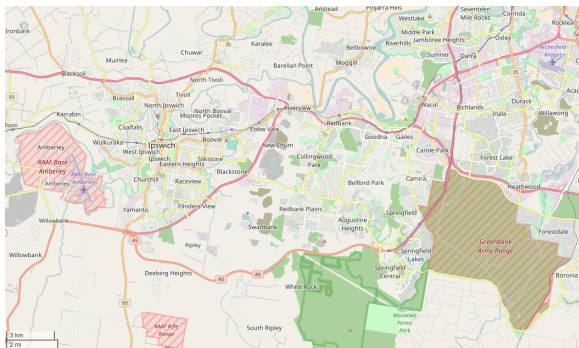
let's fly across .jpg files



that do not accurately georectify



is accuracy important?



CASR1998 REG 175

Yes



- Amberley RAAF is conditionally **RA1**
- Greenbank Army is **RA3** SFC to 2000

My nightmares are made of this stuff *(AIP EMERG 5.12)*

5.12 **Interception**

- 5.12.1 Aircraft not exempted in accordance with para 15.5, and which cannot be satisfactorily identified, may be intercepted by fighter aircraft.
- 5.12.2 If any doubt arises as to the friendly intention of an aircraft, closer identification may be necessary, in which case the identifying aircraft will maintain visual observation of the intercepted aircraft, and:
 - a. the intercepting aircraft should approach the intercepted aircraft from astern. The intercepting aircraft, should normally take up a position of the left side, slightly above and ahead of the intercepted aircraft, within the field of view of the pilot of the intercepted aircraft, and initially not closer than 300M.
 - b. the intercepting aircraft should begin closing in gently on the intercepted aircraft, at the same level, until no closer than absolutely necessary to obtain the information needed; and
 - c. if identified as friendly, make the appropriate signal to proceed from a position slightly ahead, by a climbing turn of 90 DEG to port away from the intercepted aircraft, if permissible, considering other air traffic.

Alternatively

Use non-certificated aeronautical data with restrictions on operations.

but

Fatal Accident Report ZK-SML, Mount Duppa, 09 April 2011. **CFIT**



VFR into IMC

- VFR into IMC is a dangerous flight condition where a visual pilot is required to maintain, but has lost, outside visual reference e.g. due to flying into cloud
- It is particularly dangerous if the pilot is untrained and/or the aircraft is ill-equipped to handle instrument (non-VFR) conditions
- ZK-SML is a light, VFR only, experimental aircraft with **lots** of modern technology onboard

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Accident Report excerpt (1.16.1)

Assistance was sought from the New Zealand agent for the MGL Avionics EFIS system installed in the aircraft. While reviewing the aircraft's flight path based on the SSR data on a computer based simulator, two major errors in the EFIS navigation software were discovered.

Accident Report excerpt (Figure 2)



Figure 2: EFIS screen display

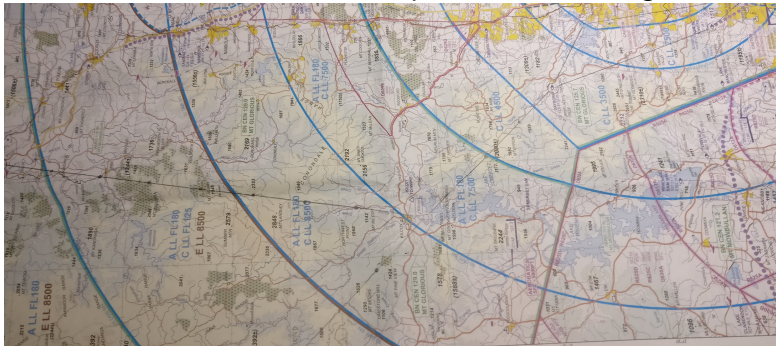
At what height is the terrain at this aeroplane's 12 o'clock position?

Accident Report excerpt (1.16.2)

It was found that the moving map display did not accurately display the 3717 feet spot height for Mount Duppa. Due to the positioning of a map join which passes through the '3', the spot height for Mount Duppa was corrupted and was displayed as 1717 feet. Refer to the spot height next to the aircraft symbol on the map display in figure 2.

Aeronautical charts

This is a real VTC, marked for a planned visual navigation exercise



- scale 1:250000
- folded, according to planned route
- pencil marked according to planned route
- pencil marks at 10nm intervals for DR exercise
- note Brisbane airspace boundaries in blue
- note radio frequencies and boundaries in green

Aeronautical charts

This is a real WAC, marked for the same planned exercise



- scale 1:1000000
- relevant airspace boundaries are transferred (red)
- relevant radio frequency boundaries are transferred (green)
- diversion is an integral part of the navigation exercise — revert to VTC

Aeronautical charts

zippers

Functions

Lenses

Don't we already have sound solutions to these problems?

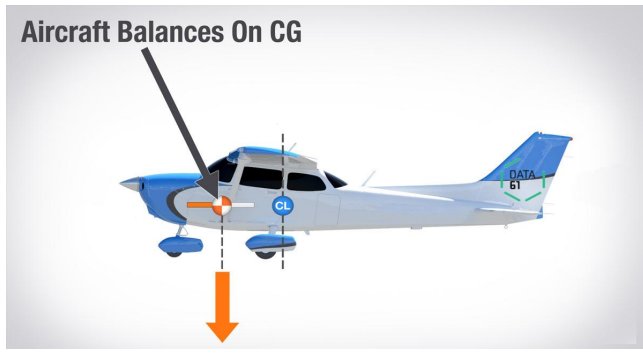
Algebraic Data Types

Traversals

Fixed-wing Aircraft Weight and Balance

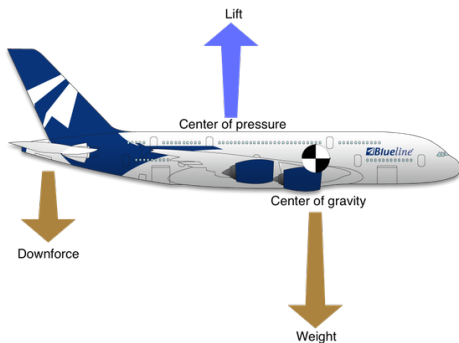
Fixed-wing Aircraft Weight and Balance

Basic principles



Fixed-wing Aircraft Weight and Balance

Same principles apply to A380



Fixed-wing Aircraft Weight and Balance

Weight, Balance *loosely speaking*

- Weight is ensuring that the aircraft is able to achieve and maintain flight within parameters.
- Balance is ensuring that the CG is positioned such that the aircraft is controllable.

Fixed-wing Aircraft Weight and Balance

Calculating Weight and Balance

- Obtain and normalise (to pounds) weights of
 - front seat PAX
 - rear seat PAX
 - baggage
 - fuel/oil
 - aircraft
- Multiply each weight by the associated *arm*.
- Sum the products and plot the result on a flight envelope for that aircraft.

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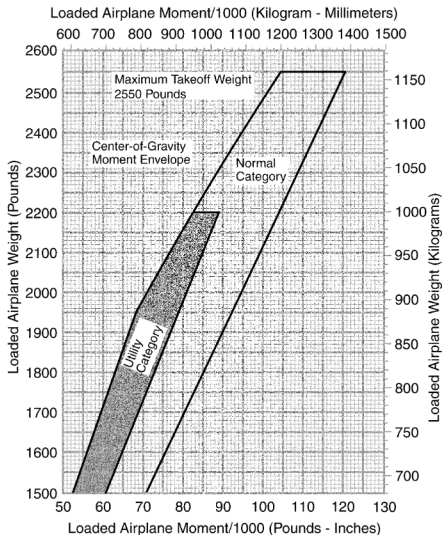
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Fixed-wing Aircraft Weight and Balance

CoG Moment Envelope

B4077



Fixed-wing Aircraft Weight and Balance

then this happens

- Operator: “We’ve changed your aircraft to VH-LSE.” *with a different empty weight*
- Jessica: “Hey is it cool if I sit in the front?”
- There is now time pressure and distractions.
- Start the calculation again, or use previous calculations and declare the difference insignificant.

Fixed-wing Aircraft Weight and Balance

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Fixed-wing Aircraft Weight and Balance

Computers can do this for us!

- W&B calculations are written in Haskell.
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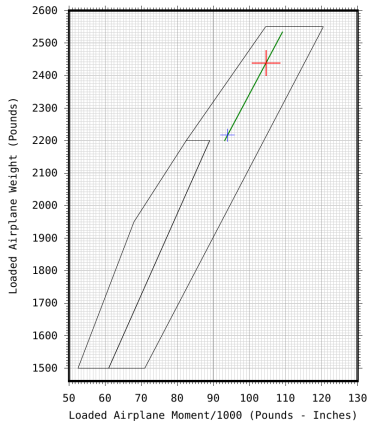
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Fixed-wing Aircraft Weight and Balance

Example result



All Up Moment	104604.13 lb/in
All Up Weight	2438.66 lb
Utility Category	NO
Normal Category	YES
Zero Fuel Moment	9384.13 lb/in
Zero Fuel Weight	2198.66 lb
Usable Fuel Moment	9394.13 lb/in
Usable Fuel Weight	2216.66 lb
Fuel at Capacity Moment	109212.13 lb/in
Fuel at Capacity Weight	2534.66 lb
Baggage A Limit	-97.95 lb
Baggage B Limit	-56.89 lb
Baggage total limit	-97.95 lb
MTOW limit	-111.34 lb
MPW limit	-119.34 lb

20170182 Flight WH-LSE PAX: George, Jess

Fixed-wing Aircraft Weight and Balance

W&B calculations:

- are revision controlled
- can be published as a library
- can be queried retroactively

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Fixed-wing Aircraft Weight and Balance

Haskell source

```
Preflight.hs
1 module Data.Aviation.Preflight where
2
3 tonymorris = 80 ^, kilograms
4 george = 85 ^, kilograms
5 jessica = 55 ^, kilograms
6 joshua = 64 ^, kilograms
7 paul = 90 ^, kilograms
8
9 vhlseBEW = 1691.6 ^, pounds
10 vhlseArms = bewC172AircraftArms (40.6 ^, inches)
11
12 vhafrBEW = 1684.3 ^, pounds
13 vhafrArms = bewC172AircraftArms (40.6 ^, inches)
14
15 flight20170102Weight :: C172Arms Weight
16 flight20170102Weight = C172Arms (tonymorris <> george) jessica (40 ^, usgallonsV . avgas100LL) (10 ^, kilograms) mempty
17
18 flight20170121Weight :: C172Arms Weight
19 flight20170121Weight = C172Arms (tonymorris <> paul) (joshua <> george) (30 ^, usgallonsV . avgas100LL) (10 ^, kilograms) mempty
20
21 flightMoments =
22 [ ("20170102 Flight VH-LSE PAX: George, Jess", vhlseBEW, flight20170102Weight, vhlseArms, "dist/flight20170102")
23 , ("20170121 Flight VH-LSE PAX: Paul, Joshua, George", vhafrBEW, flight20170121Weight, vhafrArms, "dist/flight20170121") ]
```

Automatic Dependent Surveillance – Broadcast ADS-B

ADS-B is an electronic system aboard aircraft that broadcasts a radio signal containing certain information about that aircraft, to:

- other aircraft
- air traffic control on the ground
- anyone else who chooses to receive the signal

ADS-B

- The ICAO identifier for the airframe.
- The flight identifier e.g. aircraft callsign.
- Aircraft position.
- The integrity of the position report e.g. GPS accuracy.
- Altitude as a function of barometric pressure.
- Altitude as a function of GPS.
- Rate of climb/descent.
- Aircraft ground track.
- Aircraft ground speed.
- Any emergency indicators.

ADS-B receive

- We can receive ADS-B signals on 1090MHz with a SDR.
- Raspberry-pi, DVB Tuner, 1090MHz antenna.

ADS-B receive

- We can receive ADS-B signals on 1090MHz with a SDR.
- Raspberry-pi, DVB Tuner, 1090MHz antenna.

You are no doubt wondering

In a talk at the **Black Hat USA conference**, security researcher **Andrei Costin** discussed the possibility of spoofing signals to air traffic control systems in attacks - all courtesy of roughly \$1,000 worth of equipment. After his presentation, he sat down with *SecurityWeek* and revealed more details of how attackers could exploit weaknesses in the **Automatic Dependent Surveillance-Broadcast (ADS-B)** technology.

Yes the absence of security in ADS-B has been demonstrated.

Portable ADS-B receiver hardware

Portable ADS-B receiver hardware



Portable ADS-B receiver hardware

RTL2832U Digital DVB-T (x2)



RTL2832U Digital DVB-T to receive 1090MHz

Portable ADS-B receiver hardware

Dual 1090MHz Antennae



Portable ADS-B receiver hardware

VK-162 GPS



- External GPS antenna
- Provides track, ground speed

Portable ADS-B receiver hardware

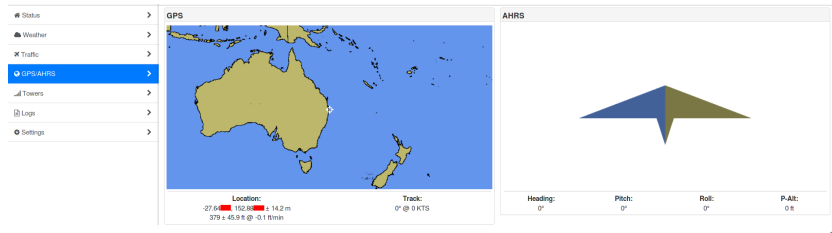
RY835AI



Gyrometer (accelerometer) providing roll, pitch and yaw

Portable ADS-B receiver software

Stratux GPS/AHRS web



Portable ADS-B receiver software

Stratux Traffic web

Menu		Stratux HELP						
Status	>	Traffic Connected						
Weather	>							
Traffic	>							
GPS/AHRS	>							
Towers	>							
Logs	>							
Settings	>							
		Flight	Speed	Altitude	Course	Location	Power (dB)	Age
		✈️ CP100	390 KTS	25,500 1000	010°	-28° 11' 40" 153° 13' 24"	-29.76	3.1s
		✈️ CP101	275 KTS	10,250 1000	200°	-27° 37' 25" 152° 6' 29"	-29.07	0.8s
		✈️ CP102	250 KTS	20,525 1000	210°	-27° 54' 15" 152° 28' 5"	-28.01	0.9s
		✈️ CP103	240 KTS	19,325 1000	220°	-28° 7' 17" 152° 2' 8"	-27.81	0.9s
		✈️ CP104	305 KTS	18,925 1000	220°	-27° 56' 24" 152° 52' 38"	-34.56	0.6s
		✈️ CP105	360 KTS	23,750 1000	200°	-28° 14' 5" 152° 48' 3"	-31.37	15.9s

Portable ADS-B receiver software

Traffic record data type

Data.Aviation.Stratux.Types.Traffic

Documentation

data Traffic

Constructors

Traffic

```
icaoAddrTraffic :: IcaoAddr
_tail :: String
_emitterCategory :: EmitterCategory
_onGround :: Bool
_addressType :: Int
_targetType :: TargetType
_signalLevel :: Double
_positionValid :: Bool
_latitude :: Double
_longitude :: Double
_altitude :: Int
_gnssDiffFromBaroAlt :: Int
_altIsGnss :: Bool
```

```
_navigationIntegrityCategory :: Int
_navigationAccuracyCategoryForPosition :: Int
_track :: Int
_speed :: Int
_speedValid :: Bool
_verticalVelocity :: Int
_timestamp :: UTCTime
_age :: Double
_lastSeen :: UTCTime
_lastAltitude :: UTCTime
_lastGnssDiff :: UTCTime
_lastGnssDiffAltitude :: Int
_lastSpeed :: UTCTime
_lastSource :: Int
_extrapolatedPosition :: Bool
_bearing :: Double
_distanceToTrafficFromOwnship :: Double
```

Portable ADS-B receiver software

Situation record data type

```
data Situation
```

```
Constructors
```

```
Situation
```

```
_lat :: Double  
_lon :: Double  
_heightAboveEllipsoid :: Double  
_geoidSep :: Double  
_satellites :: Int  
_satellitesTracked :: Int  
_satellitesSeen :: Int  
_accuracy :: Double  
_nacp :: Int  
_alt :: Double  
_accuracyVert :: Double  
_gpsVertVel :: Double  
_lastFixLocalTime :: UTCTime  
_trueCourse :: Double  
_groundSpeed :: Int  
_lastGroundTrackTime :: UTCTime  
_lastGPSTimeTime :: UTCTime  
_lastNMEAMessage :: UTCTime  
_temp :: Double  
_pressureAlt :: Double  
_pitch :: Double  
_roll :: Double  
_gyroHeading :: Double  
_lastAttitudeTime :: UTCTime
```

Portable ADS-B receiver software

Let's code!