AN-24 Accident at Nizhneangarsk, Russia

On Thursday 27 June 2019 an AN-24 of Angara Airlines, flight number 2G200, flying from Ulan-Ude Airport (UUD/UIUU), Russia was destroyed whilst landing at Nizhneangarsk Airport (UIUN), Russia. Reportedly, the left engine had failed in flight. A video of the landing taken by a passenger sitting on the right hand side under the wing was posted online.

The aircraft approaches at what seems like high speed after touchdown it veers off the runway to the right eventually colliding with a series of obstructions.

Here is some analysis of that video to give a picture of the speed, position and acceleration forces experienced by the aircraft.

Summary of Observations

- At the start of the video the aircraft is on the extended centreline of runway 22 at a distance of 2482±98 m from the start of the runway. Ground speed is 82.8±2.0 m/s, (161±4 knots).
- The ground speed slowly increases to a maximum at around t=17.0 seconds when the aircraft is 964±44 m from runway 22 start travelling at 92.7±3.5 m/s (180±7 knots).
- The aircraft crosses the start of runway 22 at t=27.5 travelling at 88.6±1.9 m/s (172±4 knots).
- Touchdown is at t=33.8 s, 549±14 m (about 1/3rd down the 1653m runway) at 84.3±0.7 m/s (164±1 knots). Acceleration is -1.1 m/s^2.

- A drift to the right starts at t=36.0 possibly due to a burst tyre. The aircraft is 731±16 m down the runway travelling at 81.8±0.9 m/s (159±2 knots).
- The aircraft departs the runway at t=46.1 s, 1463±41 m down the runway at 58.7±3.0 m/s (114±6 knots). Acceleration is -3.9 $m/s^{2.}$
- At t= 56.1 there is an impact with the boundary fence 1853m from the start of the runway. This collapses the starboard undercarriage. Impact speed is around 19 m/s (37 knots).
- 36m further on at about t=58.0 the aircraft impacts a building. Speed at this time is probably around 5 to 10 m/s (10 to 19 knots).
- The video ends at t=60.6 seconds.

Resources

Apart from the video, there is:

- Wikipedia on Angara Airlines Flight 200 and on Nizhneangarsk Airport
- AV Hearald
- Aviation Safety Network
- Videos from RT
- Hi resolution (~0.6m per pixel) imagery of the approach path, example from google maps.

Methodology

Three techniques are used to calculate the position of the aircraft:

- Matching landmarks in the video with aerial imagery.
- Counting runway details in the video to give the aircrafts ground speed.
- Calculating the likely progress of a ballistic body.

Landmarks in the Video

The video shows some distinct landmarks, in particular some colourful and readily identifiable buildings. These can be seen on aerial imagery and used to find the aircraft position on the extended centreline of runway 22 (the aircraft appears to make a straight in approach with little lateral deviation).

Here are two examples. Frame 1 (t=0s) shows the line up of the edge of a settlement with a dark smudge on a sandy part of an island. The magenta line shows the estimated ground line the aircraft is flying across, the red line is the extended centreline of runway 22:

This puts the aircraft 2490±98m from the start of runway 22.

The second example is frame 483 (t=16.0s) where a two distinctive buildings are lined up:

This puts the aircraft at 1041 ±49m from the start of runway 22.

There are numerous opportunities here but around 15 measurements are sufficient to establish the flight path. The measurement is of distance and this can be differentiated to give velocity. Errors in this method is estimated to be ±100m when 2500m from the runway, reducing to ±10m at the runway edge.

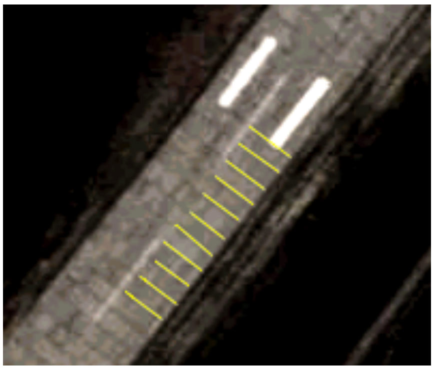
This technique is useful but it requires identifiable ground features and few exist after the aircraft crosses the threshold, and none once 330m beyond the start of runway 22. Fortunately another technique exists which is due to the particular construction of this runway and typical of Siberian airports. Even better, these two (independent) techniques overlap for about four seconds so they can be cross checked with each other.

Counting Slabs

The runway at Nizhneangarsk is made of concrete slabs that are ubiquitous in Siberia for roads and airfields. This gives the runway a particular pattern where vegetation growth or water staining occurs at the slab edges that contrasts with the pale concrete of the slab. These edges can be clearly seen, and measured, on the video and high-resolution aerial imagery. The aircraft's progress across these slabs can be used to calculate the velocity. That can be integrated for distance or differentiated for acceleration.

Standard Slabs

Standardised slabs used for roads and runways in Siberia measure 6m x 1.8m (data from the author's engineering file). For confirmation here is an enhanced aerial image where the south side of the runway has been annotated, rather crudely, with yellow lines at the edge of each slab (the slabs are laid with their long side in the runway direction).



Careful measurement of this imagery shows that these 10 slabs are 98 pixels long which, at 0.617 m/pixel for this image, gives a slab length of 6.05m. The value of 6m for slab length is used hereon.

Speed by Slab Transits

These slab edges can be seen quite clearly on the video. As an example here are two frames [841 and 843] and they are 1/15 second apart (at 30 fps).

For clarity the edges of the slabs are identified with yellow lines:

The broad line on the left image is the same part of the runway as the line on the right image. So the near match of the right hand line in the left frame with the line in the second frame indicates that the aircraft has traveled almost exactly 6m in that 1/15th second. This gives a ground speed of 90 m/s (175 knots).

The light patch on the right of the concrete, and the lightish patch in the grass that confirms this sequence.

This is a speed measurement and can be integrated for distance or differentiated for acceleration.

TODO: Lots from hereon.

Analysis

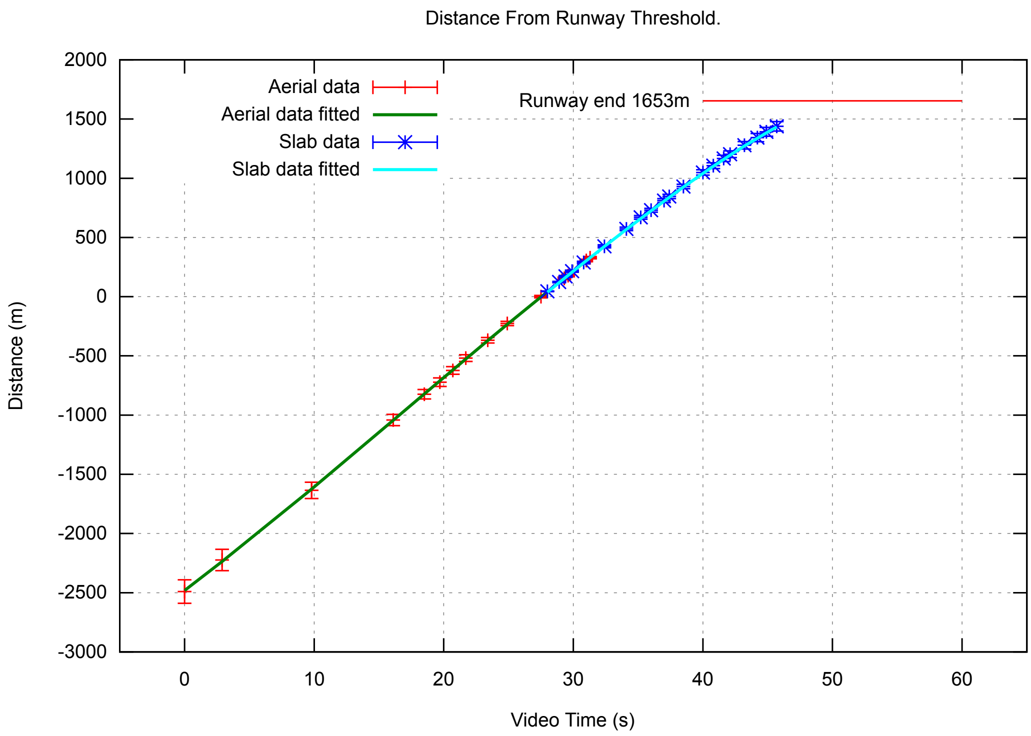
There are several sets of measurements calculated independently from each other:

- Comparing the video to aerial imagery which gives the aircraft position over time. This can be differentiated for aircraft ground speed.
- Counting concrete slab transits that can give the aircraft ground speed over time. This can be integrated for aircraft position and differentiated for the longitudinal acceleration of the aircraft.
- The aircraft impacts a boundary fence at t=56.1, by comparing this with the last known speed and position an estimate of the impact speed can be made.

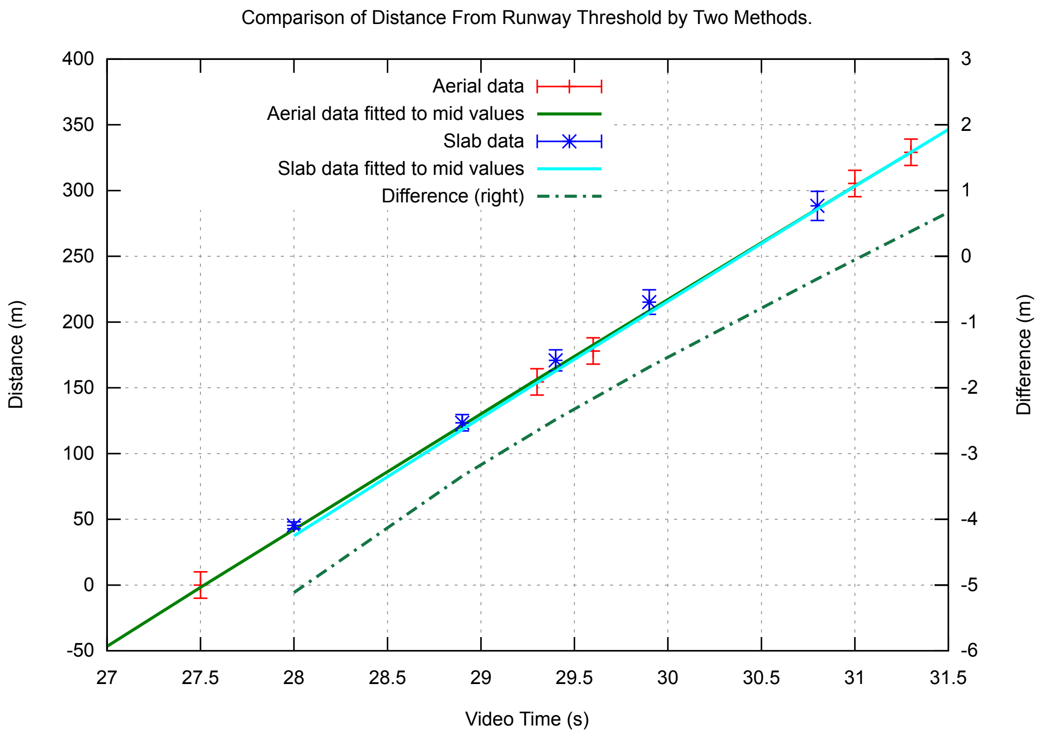
Computed Data

Position

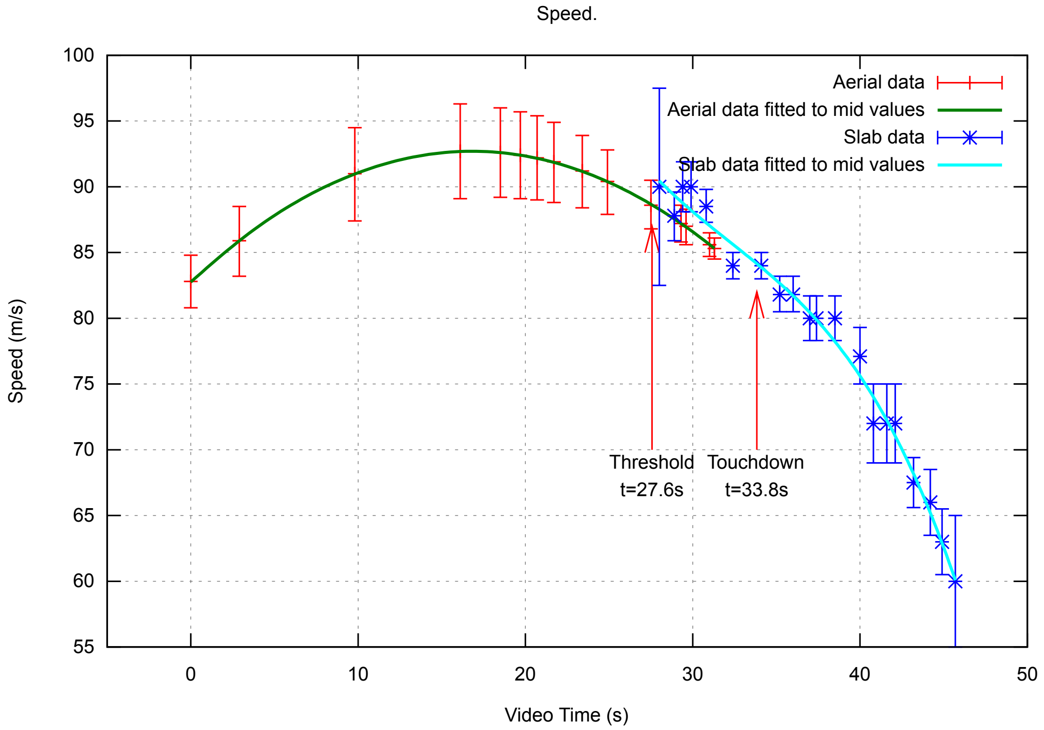
TODO

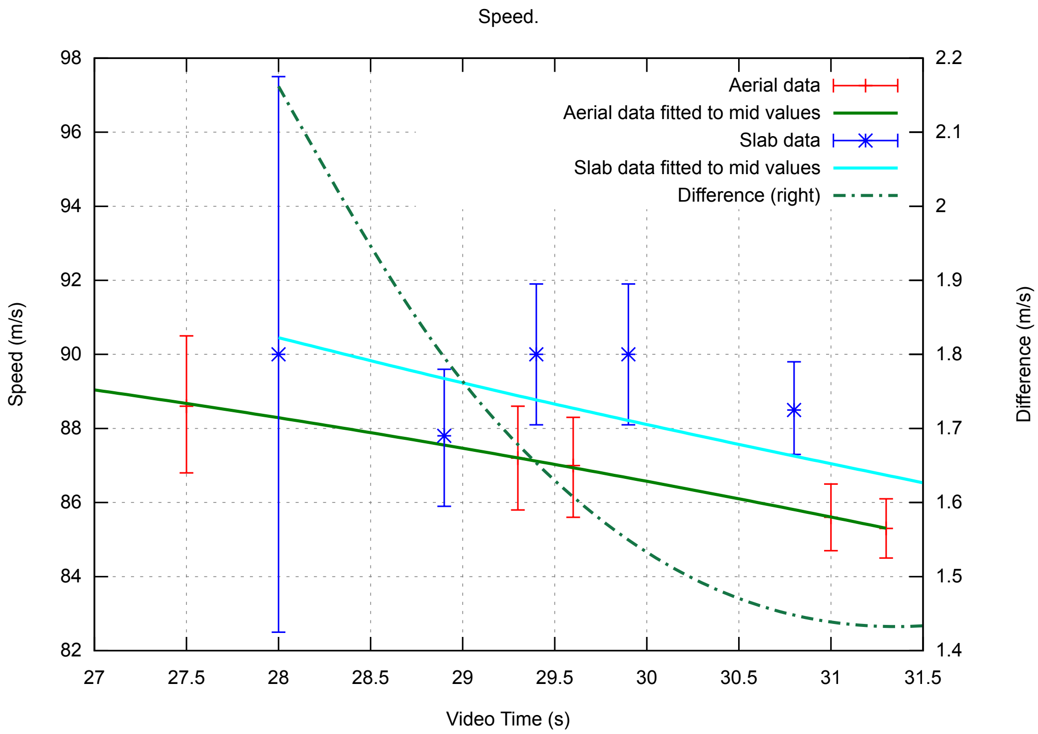


TODO

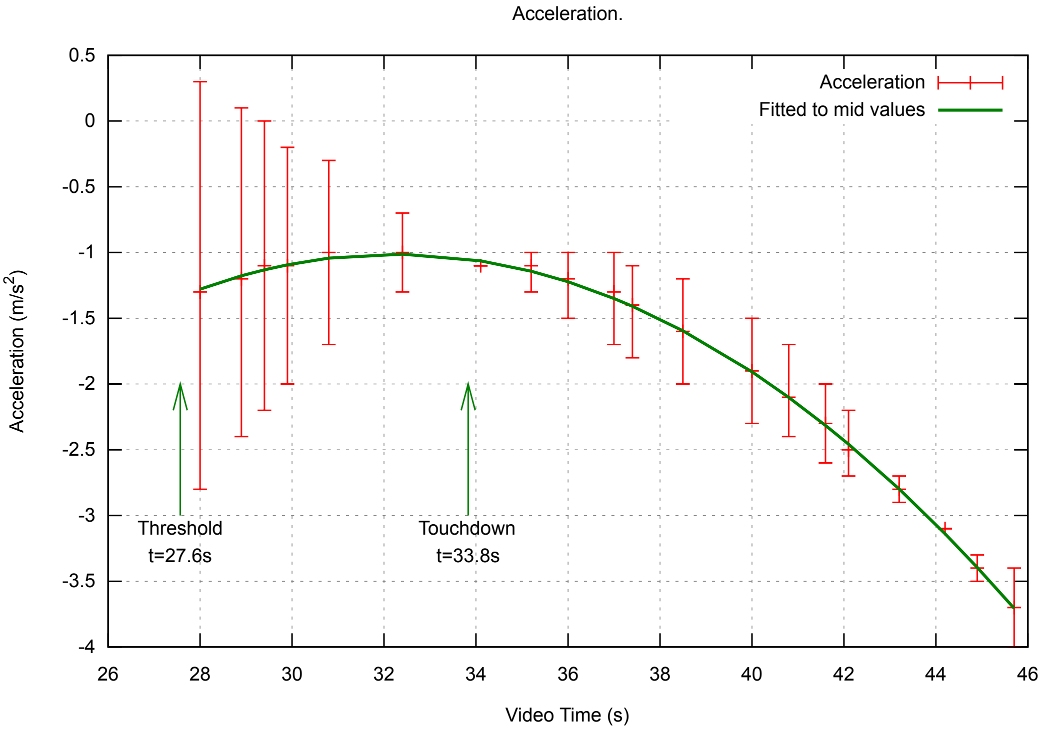


Ground Speed





Acceleration



Boundary Fence Impact

The sequence below shows four consecutive frames from the video of the starboard undercarriage collapse as the aircraft goes through the airfield boundary.

The first frame [1684] shows the moment before impact, the obstruction is on the left which looks like as substantial concrete block, the dark disc at the bottom is the tyre and the silver vertical is the undercarriage leg. The second frame (t=56.1s) shows the moment of impact and the last two frames show progressive collapse of the starboard landing leg. The last frame is rotated somewhat to right, most likely due to the forces on the person filming which would naturally rotate a hand held camera to the left.

Boundary Fence Impact Speed and Acceleration

It is possible to estimate the speed when the aircraft hits the boundary.

Time (s)	Position (m)	Ground Speed (m/s)	Acceleration (m/s^2)	Description
45.7	1441.5 ±98	60.0 ±3.1	-3.7 TODO	Last computed position.
56.1	-964 ± 44	180 ±7	0	Boundary fence impact.

- The last measured position was at t=45.7 s, v=60.0 m/s, d=1441.5 m.
- Video time of the impact is t=56.1 seconds and the distance of the fence from the threshold is 213 m beyond the runway edge at d=1652 + 213 = 1865m.
- The difference in time is 56.1 - 45.7 = 10.4 seconds and in distance is 1865 - 1435.5 = 429.5m
- This implies an average velocity of 429.5 / 10.4 = 41.3 m/s.
- If the object is constantly (de-)accelerating from a starting velocity of 60.0 m/s implies a change in velocity of 2 * (41.3 - 60) = -37.4 m/s.
- This would give a mean acceleration -37.4 / 10.4 = -3.6 m/s^2 which is consistent with the last calculated acceleration of -3.7 m/s.
- This gives an impact velocity of 60.0 - 37.4 = 22.6 m/s (44 knots).

Initial v=60.0 (m/s) d=1441.5 (m) terminal v=21.5 (m/s) acceleration=-3.7 ($m/s^{2)}$ stop= 5.8 (s) stop in =62.5 (m) Initial v=63.2 (m/s) d=1481.3 (m) terminal v=10.8 (m/s) acceleration=-5.0 ($m/s^{2)}$ stop= 2.1 (s) stop in =11.5 (m) Initial v=56.9 (m/s) d=1401.8 (m) terminal v=32.3 (m/s) acceleration=-2.4 ($m/s^{2)}$ stop=13.6 (s) stop in =219.6 (m)

Final Impact

TODO

Summary of Events

TODO

Time (s)	Position (m)	Ground Speed (knots)	Acceleration (m/s^2)	Description
0.0	-2482 ±98	161 ±4	N/A	Start of video.
17.0	-964 ± 44	180 ±7	0	Maximum ground speed.
27.0	0 ±10	172 ±4	N/A	Start of runway 22.
33.8	572 ±15	163 ±2	-1.1	Touchdown.
45.6	1438 ±40	116 ±10	-3.7 ±0.3	Last calculated speed and position.
TODO	est. TODO	est. TODO	est. TODO	Departure from runway.
TODO	est. TODO	est. TODO	est. TODO	Impact with airfield perimeter, undercarriage collapses.
est. TODO	est. TODO	est. TODO	est. TODO	Final impact.

Table 7: Selected Events