Analysing Flight Data to win a Red Bull Air Race

• Peter Wezenbeek @ Mathworks 8 May 2018
Red Bull Air Races - History

- “The fastest motorsport on the planet”
- A combination of high speed, low altitude and extreme manoeuvrability
- Inaugural season as a World Series in 2003
- After 8 seasons, a break of 3 years to redefine the format
- Returned in 2014, with an introduction of standardised engines and propellers, as well as improvements to the rules and regulations
- Current format: 14 pilots competing in eight races across the globe
Red Bull Air Races - Format

- Navigate an aerial racetrack featuring air-filled pylons in the fastest possible time, incurring as few penalties as possible.

- In all flying sessions, only one pilot races in the track at a time.
  - **Qualifying**: two mandatory qualifying sessions. Best time counts.
    - Results of the qualifying session determine the order of racing on Race Day.
  - **Round of 14**: head-to-head heats.
    - the seven winners plus the fastest loser move forward to the Round of 8.
  - **Round of 8**: head-to-head heats again.
    - The four winning pilots advance to the Final 4.
  - **Final 4**: race individually and victory is based on the quickest time recorded for the session.
Red Bull Air Races - Locations
Red Bull Air Races - Penalties

- Penalties are applied to the flying time for:
  
  - Hitting a pylon
  - Flying too low / too high
  - Incorrect level through a gate
  - Flying over the crowd line
  - Not enough or no smoke
  - Track entry speed too high
  - Over G (max 12G limit or more than 0.6 s over 10G)
Red Bull Air Races - Planes

- Zivko Edge 540 and MXS-R
- Standardised engines (300hp Lycoming) and propeller (Hartzell)
- Winglets or no winglets
Red Bull Air Races - Pilots

- Master Class pilots will have obtained their Unrestricted Superlicence
- Challenger pilots can only apply when minimum criteria set by the Red Bull Air Race Committee, include top achievements in international flying competitions organised by the FAI.
- Various backgrounds; aerobatic champions, commercial airline captains, fighter pilots
Racing background
Flight Data - Harvesting

- What sort of data?
  - Aircraft – Airspeed, G-force, roll rates
  - Engine – RPM, Temperatures, AFR, pressures
  - Pilot – Groundtrack, video

- How is data recorded?
  - Custom designed WINGMATE gateway
  - Connects to different sources
  - Sends data to a commercial video system
Flight Data - Harvesting

WINGMATE Internal sensors
- 3 axis G-force plus gyro

DAAMS Flight performance sensors
- Air speed
- Pressure altitude

MVP-50 Engine sensors
- RPM
- Manifold and oil pressure
Data analysis - Why Matlab?

- Handling large data files
- Decoding the data format
- Analyse data with automated scripts
- GUI interface for ease-of-use
- Data presentation and automated reporting

- Track and racing lines simulation with Simulink
- Simulink for ground track reconstruction
Entering Start Gate

Fuel Flow: +0.347 l/h
Lateral: +0.001 g
G margin: +12.9 G
GPS speed: 204 kts
G force: +1.1 G
IAS: 187 kts
Flight Data – Analysis

- What to do with all this data
  - Data analysis to quantify
    - Aircraft performance
    - Engine performance
    - Pilot performance
- WINGMATE has developed specific analysis tools based on the MATHWORKS platform for
  - Ground track reconstruction and analysis
  - Energy management analysis
  - Engine peak performance reporting
- Matlab is used for GUI’s and automated reporting
- Simulink is used for ground track reconstruction
GUI’s for Automated Analysis
Red Bull Air Races - Track
Model Based Ground Track Reconstruction

Figure 4.2: The aircraft coordinate frame.
Reconstructed Ground Tracks
Race Performance Analysis

- Loss of speed
- S turn entry
Race Team

- Team coordinator
- Pilot
- Technician
- Tactician
Race Week - Timeline

- Monday – TC and Technician arrive and build the plane
- Tuesday – Pilot arrives
- Wednesday – Test flight, Tactician arrives
- Thursday – Test flight
- Friday – Practice sessions
- Saturday – Practice and Qualifying
- Sunday - RACE
Race Week – Race day

- 8.00 Team breakfast
- 11.00 Pilot parade
- 13.00 Round of 14
- 15.00 Round of 8
- 15.30 Final 4
- 16.00 Podium ceremony
- 17.00 Dismantle aircraft
- 22.00 .....
Please ask!