The Coming Electric Revolution

Dr. Steve Wright

Senior Lecturer, Avionics and Aircraft Systems

Department of Engineering, Design and Mathematics
Steve Wright

- Rolls-Royce 1989-97
- STMicroelectronics 1997-2000
- Airbus 2001-2014
- University of Bristol 2006-2009
- University of West of England 2014-
Dubai announces passenger drone plans

A drone that can carry people will begin "regular operations" in Dubai from July, the head of the city's Roads and Transportation Agency has announced.
eHang 184 passenger drone

"I'd have to be taken on board kicking and screaming."
Expensive Drones

Bae Systems
Taranis

General Atomics
Predator

AeroVironment
Puma
Cheap Drones

DJI Inspire

Parrot AR.Drone

JRCC H2O
Comparison

A de-costed Eurofighter

A de-costed iPhone, or an enhanced Raspberry Pi
Revolution by Evolution

- No fundamental breakthroughs
- Multiple technologies have evolved along their performance/cost curves
- Converged to enable system-level breakthrough

GitHub
Enabling Technologies

- 32-bit microprocessors
- 6-axis accelerometers
- Barometers
- GPS
- Open-source software
- Digital telemetry links
- Cameras
- Displays
- Batteries
A new industry

Builders

Operators
It is 1917
**The opportunities**

Intra-city in the short term

“Sub-regional” airlines

Hundreds of taxi-ports*:

- Licensed & unlicensed airports
- Heliports & helipads
- Glider fields
- Microlite fields

* Darrell Swanson – AviaSolutions
The challenges

- Powertrains
- Avionics
The challenges

- Powertrains — Energy density
- Avionics
The challenges

• Powertrains – *Energy density*

• Avionics - *De-skilled operations*
Power

• The *rate* of converting energy from one form into another

• Measured in *Watts* (*Joules* per second)

• For electrical systems:

  \[
  \text{Watts} = \text{Volts} \times \text{Amps}
  \]
Power density (kW/kg)

5.67*

0.65*

1.5*

*Terms and Conditions apply
Energy

- The ability to do work
- Measured in Joules
Energy density (MJ/kg)

46.4
Energy density (MJ/kg)

46.4

37
Energy density (MJ/kg)

PETROL: 46.4
LARD: 37
DYNAMITE: 4.6
Energy density (MJ/kg)

- Petrol: 46.4
- Dynamite: 4.6
- Lard: 37
- Battery: 0.95
Power – a roadmap

- IC
- Hybrid (IC or Turbine)
- Enhanced Battery/Fuel Cell
Fuel Cells

- Hydrogen

- Hydrocarbon FC: eTransport’s “fusion power”
Avionics - reliability

• **Availability** (does what we want)

• **Integrity** (doesn’t do what we don’t want)

Drones are bad at both...
Reliability/Cost

<table>
<thead>
<tr>
<th>Cost ($)</th>
<th>MTBA (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-16</td>
<td>20,000,000</td>
</tr>
<tr>
<td>Predator</td>
<td>4,000,000</td>
</tr>
<tr>
<td>Puma</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Inspire</td>
<td>1,000</td>
</tr>
<tr>
<td>AR.Drone</td>
<td>300</td>
</tr>
<tr>
<td>H2O</td>
<td>30</td>
</tr>
</tbody>
</table>

Cost
The Gap of Six Zeroes

Average time between catastrophic failure

$10^3 \rightarrow 10^9$

$10^2-10^3$ hours (?)

$10^8-10^9$ hours
Simplex

- Low Availability
- Low Integrity
Duplex

- Improved Availability
Triplex & COM/MON

- High Availability
- High Integrity
How to get from here....
...to here?
Things we need to think about...

- Propulsive lift
Things we need to think about...

- Propulsive lift
- Energy storage and transfer
Things we need to think about...

- Propulsive lift
- Energy storage and transfer
- Rotor containment
Things we need to think about...

- Propulsive lift
- Energy storage and transfer
- Rotor containment
- Communications
Things we need to think about...

- Propulsive lift
- Energy storage and transfer
- Rotor containment
- Communications
- Systems/software reliability
Things we need to think about…

- Propulsive lift
- Energy storage and transfer
- Rotor containment
- Communications
- Systems/software reliability
- Certification
The eVTOL roadmap

• Many projects started by trying to simultaneously solve both the Avionics and Powertrain issues
• Players now seem to be going to two-seat configurations to introduce pilot to jump the gap
Reflections

- eVTOL technology can revolutionize General Aviation
  
  - Early entrepreneurs are inserting intermediate steps into original plans to get there
Questions?