Micro-Aerial Vehicles
Materials & Structures

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### Micro-Aerial Vehicles Materials & Structures

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Standard Form 298 (Rev. 8-98)
Proscribed by ANSI Std Z39-18
Where are we now?

- Simple platforms
- Mini rather than Micro
- Hobby shop materials
  - balsa wood; polystyrene foams; sticky tape ...........
- Aero-modelling technology
- Lack of integration
Where do we need to be?

- Lighter weight
- Damage tolerant
- Reduced size
- Engineered joints
- Integrated design
- Multi-functional
- Designed for purpose
How do we get there?
Integrated system of systems

- **Drive/propulsion**
  - Rotors
  - Wings

- **Power**
  - Drive
  - Sensors
  - Actuation
  - Communication
  - Computation

- **Actuation/Effectors**
  - Control surfaces
  - Sensor deployment

- **Fuselage**
  - Integrate
  - Protect
  - Function

- **Communication**
  - Transmit
  - Receive

- **Computation**
  - Navigation
  - Decision making

- **Sensors**
  - Acoustic
  - Visual
  - Chemical

- **Actuation/Effectors**
  - Control surfaces
  - Sensor deployment

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The Technical Drivers [1]

To design, manufacture and deploy miniature airborne military platforms of typical size 20 - 150mm : [components ~0.1 to 10mm].

- Mass and volume efficient materials - specific strength, stiffness.....
- Structural forms - foams, spaceframes, anisotropy.....
- Robustness - shock resistance, self-healing.....
- Structural integration - stress/heat transfer, cross-talk.....
- Actuators - force, strain, bandwidth, power.....
- Biologically-inspired materials & mechanisms - nano, folding.....
The Technical Drivers [2]

- Material and structures characterisation - scaling, micro-testing...
- Multifunctional materials - integrated actuation, antennae, power.....
- Low observable treatments - acoustic, vis/IR, radar.....
- Machining and shaping - moulding, milling, MEMS.....
- Joining techniques - adhesives, snap-fit, electrical...
- Assembly / deployment / recovery - quick fit / release
- Affordability - materials, manufacture, re-use, commercial infrastructure.....
Military need

- Military need $\Rightarrow$ Mission $\Rightarrow$ Device performance $\Rightarrow$ Device design $\Rightarrow$ Structures $\Rightarrow$ Materials
  - payload mass, range, speed, environment,
  - one-shot/re-use, loiter time......

- Leads to description of vehicles properties
- Leads to materials and structure requirements
- Mission scenarios needed to allow detailed directed materials and structures research and development
- Useful underpinning activities $\Rightarrow$ ‘toolkit’
Mass and volume efficient materials

- Specific strength
- Specific stiffness
- Elasticity
- Specific conductivity
- Specific power density
- Thermal conductivity

- For all electric MAVs - primary power chain
Structural forms

- Foam core sandwich materials
- Novel core sandwich materials
- Space frames
- Curvilinear forms
- Anisotropy
- Micro-foamed polymer materials
  - reinforced (fibres, nano-platelets)
- Micro-foamed metals
  - syntactic, blown
Biological-inspiration

- Nano-composites
- Folding extensible structures
- Aeroelastic structures
  - anisotropic structures
- Curvilinear, foam core and space-frame
- Smooth ‘simple’ resilient outer surfaces
- Protection of vital systems
- Don’t attempt to copy nature, be inspired
Machining and forming processes

- Moulding - model kits - cheap, poor tolerances?
- Milling & ‘micro engineering’ - the watch industry
- MEMS - 2D / Quasi 3D

Joining

- Sub-component designs - integrated assemblies
- Fixing, snap-together - manufacture & operational assembly
- Adhesives - droplet size / wetting
- Weld / solder - heat affected zone
- Electrical - power & data
Structural integration

- Stress transfer
  - large surface to volume ratio
  - bond edges / heat affected zones
- Heat transfer
  - high power / compact device
- Layout restrictions
  - sensors / effectors
- Adverse interactions
  - cross-talk (proximity)
- Affordable manufacturing

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Multifunctional structures

• Integrated actuation - lubrication / gaps (dirt ingress)
• Antennae
• Energy storage
• Low observability
Actuators

- **High specific** force & strain, bandwidth…..
- Rotary, linear or reciprocating
- Power requirements

![Graph showing stress-strain product vs. frequency for different actuator types.]

Approximate area for MAV actuators

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Deployment systems

- Assembly / shape change for launch
  - automatic vs. hand assembly
  - latching actuation
- VTOL / cassette / hand / rolling launch
  - low shock launch to flight speed
  - pneumatic, ‘bungee’.....
- Munitions launch
  - high shock launch, flight to operational area
  - rocket, mortar, shell......
- Landing - rolling / net / crash.....

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QinetiQ
Robustness

• Storage, transport, launch, collision, landing...
• Shock / impact resistance, self-healing, quick-release, spares kit.....
• Environmental robustness
[ all weather operations....]
Affordability

- Materials
- Manufacturing
- Commercial infrastructure
- Production volume
- Dual-use
- Re-usability
- Repair
Some thoughts to remember

- Primary power train remains heaviest subsystem
  - how can we make this SIGNIFICANTLY lighter
- Nature has evolved competent MAVs
  - inspirational, but different ‘mission’
- Plethora of materials and structures that could be used
  - be selective, simple designs, simple lines if you can
- Think ‘multifunctionality’
- Small component engineering
  - need true 3D machining at 0.1 to 10mm range
- MAVS will crash, collide and be handled by people in a hurry
  - robust materials and designs - think of MAVs for 3yr olds!