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MAV Design Integration

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The views expressed in this presentation are those of the author and do not necessarily represent the views of Dstl nor MOD.

Why Integration ?

- For all systems we need to consider integration to reduce risk, cost, enhanced performance, reliability……..
- For large systems the solution is

  often interfacing discrete components

Courtesy of Northrop Grumman

- However for MAV integration is more important
- As size decreases we look for integrated multi function components and innovative solutions
  - Limited volume, area and mass
  - Limited power

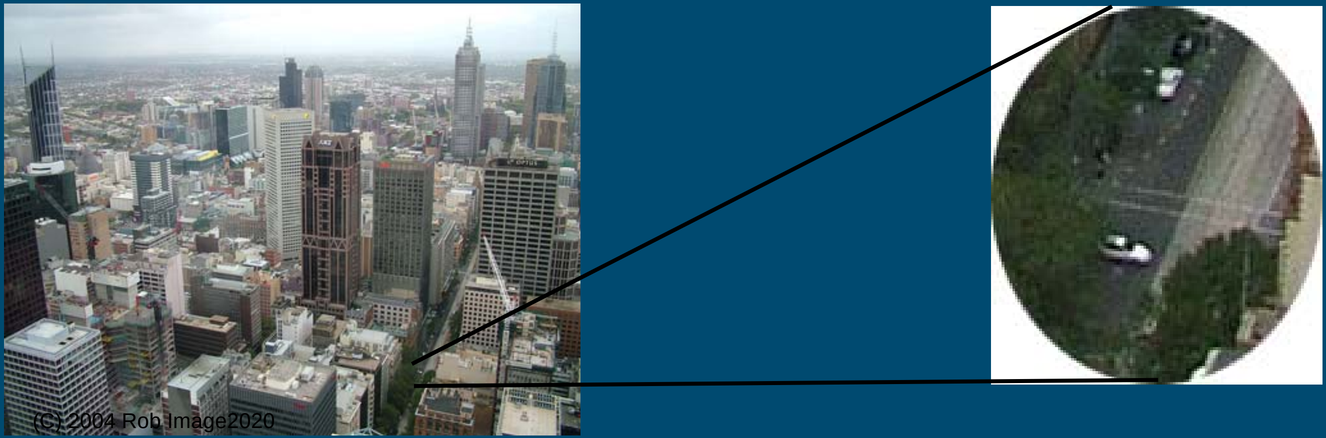
All systems need to be integrated into the operational environment

Courtesy of Blue Bear Systems Ltd (BBSL)

The Challenge

Solving the flight problem was the first step

In urban operations we have more difficult problems



MAV must have utility

Affordability

- Not only do they have to do tasks but they need to be affordable
  - Initial cost
    - A function of numbers
    - Disposable v re-usable
  - Support cost
    - Disposable
    - Are they field reparable if so do they use standard materials/components (duct tape, adhesives…)
  - Logistics costs
    - Spares
    - Consumables eg batteries
    - Protection in transport
    - Robustness if man portable
  - Integration cost into infrastructure
    - Cannot avoid some integration (eg communications)

Capabilities - environment

- Ideally all weather operations
- Small vehicles tend to have problems with penetration into wind coupled with desire for long endurance
- Turbulence can be a problem - gusts in urban areas
- Aerodynamic neutral stability gives non rotational gust response - translates not rotates - good for sensor performance
- Day/night sensing options desirable
- There will be conditions in which flight is not realistic
- Can we convince the users that this is acceptable ?

Capabilities - sensing

- What capabilities are we looking for ?

- Observe

using

rf emissions

Acoustic

Chemical

Biological

Optical thermal

Seismic ?

- Search

Dynamic

Hover

Park and stare

Cover area

Sensor and

Vehicle

Requirements

Courtesy of BAE Systems

Capabilities - sensing

- What capabilities are we looking for ?

- Track
- Discriminate

through

Environment
Clutter
Confusion
Obscuration
Stop/start

- Locate

Relative to

GPS
Map
Image or features

Multi-spectral
Processing

Off board
On boards

System
Requirements

Sensing integration issues

- Sensor size and mass
  - Many of the performance parameters vary as a function of size
  - e.g. Optical trades
    - With small systems good image quality requires you to get close
    - Want large aperture for brightness and resolution but increases weight
    - Small systems tend to be wide angle (short focal length)
    - Ability to zoom limited by weight and/or resolution (diffraction limited by the aperture)
    - Design to minimise stabilisation requirements
- Processing power
  - Potentially a lot available but need to watch power consumption and heat dissipation

Communications integration issues

- Required for control and information transfer
- rf spectrum is limited and highly congested
- Control is needed for operational utility and safety
- Autonomy can reduce communications needs
- Sensor info transfer to human to give operational utility
  - Images need wide bandwidth comms or long times but data compression can help
  - On-board processing can have heavy power demands
  - Team UV data sharing and information fusion desirable but requires comms and on-board processing
- Operator situation awareness is needed for control but is a trade with on board autonomy
- Communications range is function of frequency, power and antenna – small size vehicles tend to push you towards high frequency for on board antenna or wire antenna.
- Line of sight communications can be a limitation in urban areas or for low flight systems – use of relay can be an option
- Robustness of communications link is a key issue for military users

Integration options - Energy

- Propulsion options
  - Combustion engines tend to be noisy, high power available
  - Electric – battery energy storage/motor technology improving rapidly
  - Fuel cells – good potential
  - Hybrid
- Energy conservation/harvesting
  - Aerodynamic efficiency, assisted launch
  - Gliding, use of thermals
  - Use structural flexing to generate energy

"Structural" hydrogen fuel cell powered flight March 2003

AeroVironment Inc "Hornet"

Blue Bear Launcher

Integration options - Mission Systems

- Sensors
- Communications
  - LOS, wireless networks, LEO satellites
- Flight control
  - inertial (MEMS), airdata, biomimetic
- Navigation
  - GPS, terrain/scene referenced, SLAM, radionav
  - collision avoidance, (sensor based)
- Flight management
  - dynamic re-planning, agent based autonomy


Courtesy of Blue Bear Systems Ltd (BBSL)

"SNAP"

Integration Challenges - Control

- The human operator is legally in control
- However
  - we need to minimise communications use and bandwidth demands
  - we need an HMI which enables effective use of the system in minimum size and cost
  - we need minimum specialist operator training and skills
  - we need robustness against loss of communication
  - tele-robotic control is impractical
- I suggest we need high level of “behavioural” autonomy
- Where appropriate we need single operator control of a team of unmanned systems working together

What is autonomy ?

- It is not just automation :
  - pre-plan everything, download into system and execute
  - if things change unexpectedly during the mission - cannot react !
- Autonomy involves decision making within the air vehicle
  - the ability to react to unplanned events
  - the ability to operate with commands coming at a high level of abstraction - behavioural control
  - the ability to work with other unmanned systems as a team/pack/swarm
  - autonomy is a mission system capability with the aim of enhancing capability
  - autonomy is not black and white, there are “levels”

What is autonomy ?

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  - preplan every ... ecute
  - if things ...
- Autonom ... air vehicle
  - the a...
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  - autonomy is a mission system capability with the aim of enhancing capability
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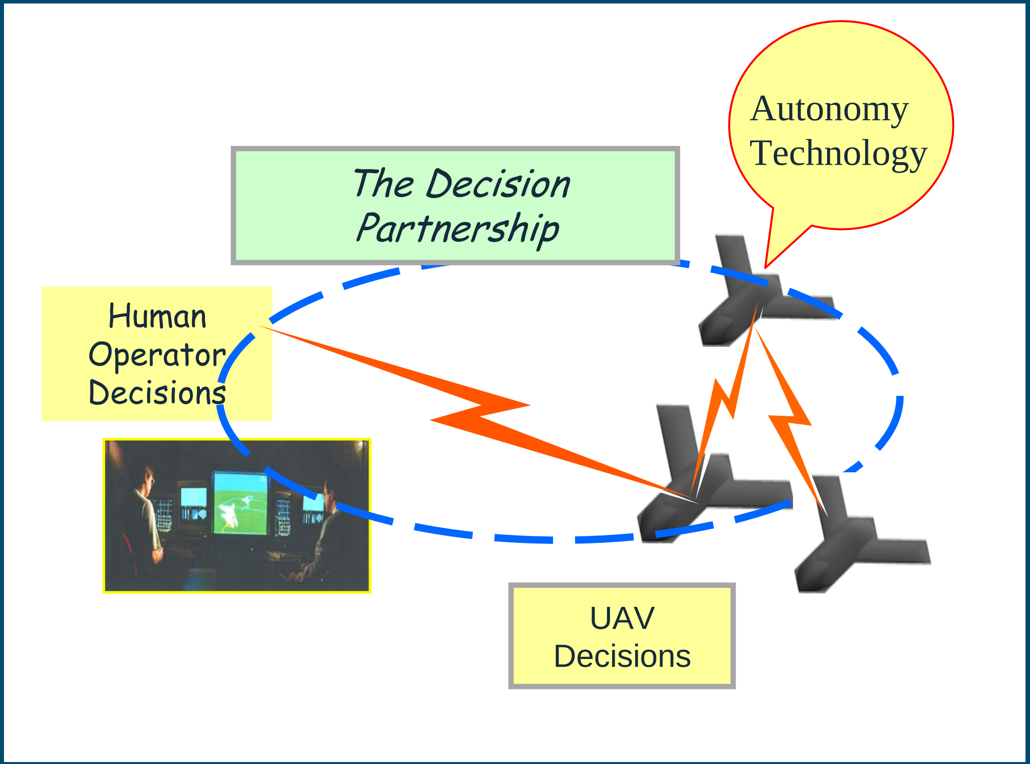
Autonomy is the ability of a system to make its own decisions

UAV Decision Partnership



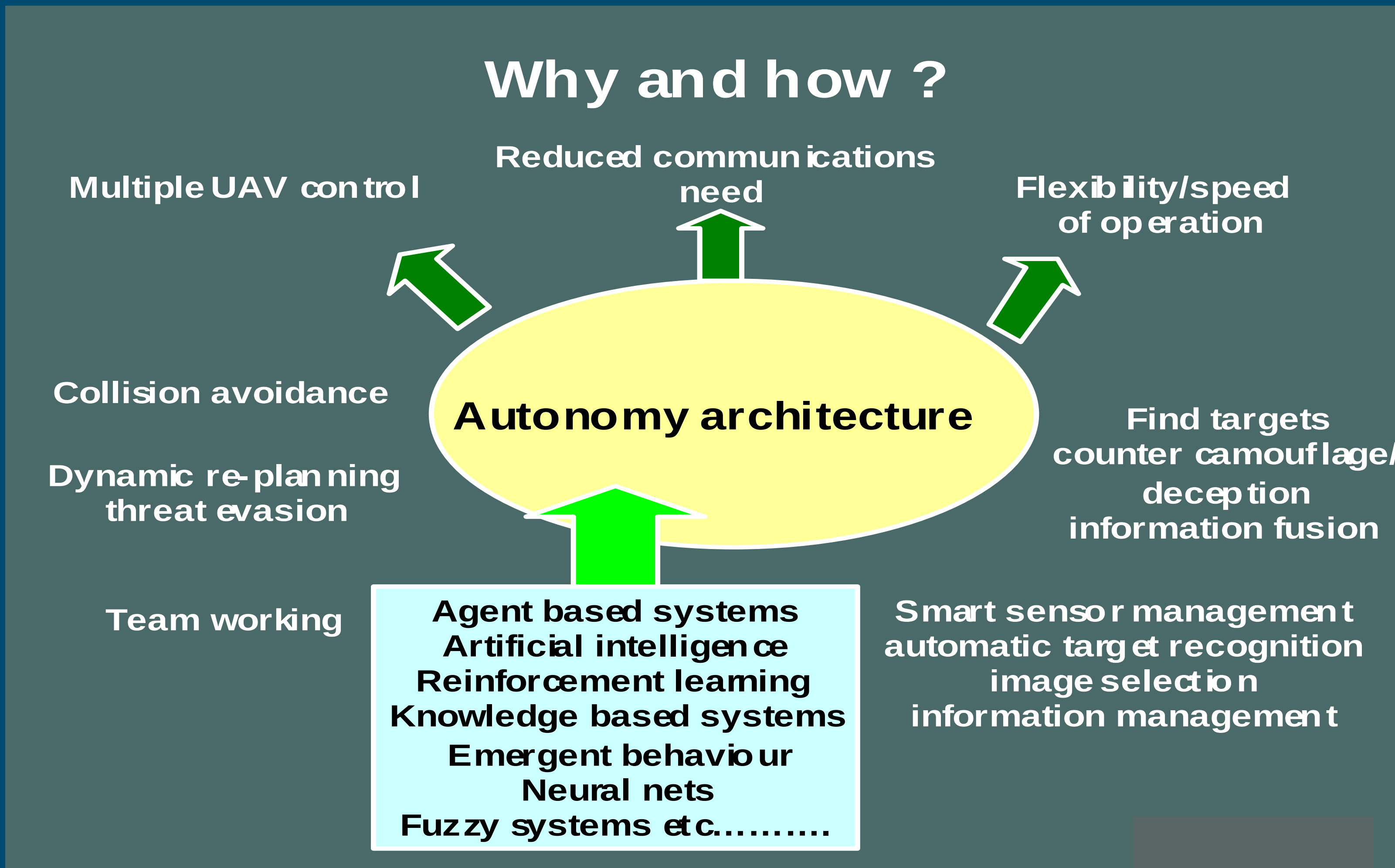
Advanced autonomy becomes a partnership between decision making by the human and technology within the vehicle

The operator makes the decisions a human has to make.

Nature of the Partnership

- The human is in control and permits the UAV to have freedoms
- Legally the human is responsible
- “Trust” is critical, can only be developed through experience and demonstration
- The level of Trust required is a function of risk and consequences.
- The level of trust you have is a function of perceived probability of the correct action
- Today UAV have basic capabilities and can follow rules, introducing knowledge/reasoning is restricted by concerns of safety, validation and certification

Autonomy Implementation



Team working

- Integration should also include team operation
- Air vehicles or mix of air/surface (parked AV or ground vehicles)
- Decentralised data fusion to maximise information collection and gain
- Multiple sensor information

  collection and fusion
- Cross cueing

Future Integration Issues

- Safety is always an issue - the more complex the system the more difficult (and costly) is certification (cannot always rely on flight termination)
- Introducing intelligence into the systems (autonomy) increases the software complexity system with the risk of high validation and verification costs if “trust” is to be established
- System vulnerability to attack and countermeasures needs to be considered
- The extent to which environmental challenges can be overcome - what is system availability ?

Can we depend on the system when we need it ?

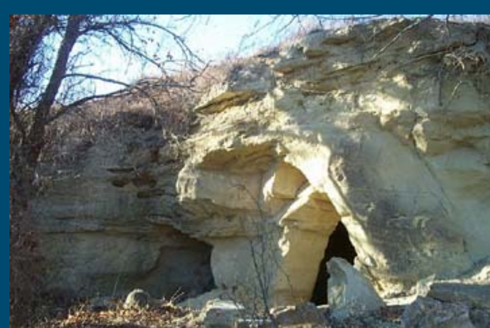
Conclusion

- Integration covers :
  - internal system capability
  - and integration into the real and operational world
- The former of these has progressed we have useful systems - autonomy and team capability are being developed and demonstrated
- There are still challenges to getting wider user acceptance including achieving cost effectiveness and flexible operation
- The big challenge is to integrate the systems effectively into the wider real world
- This competition has shown true innovation, practical integration and great prospects for the future

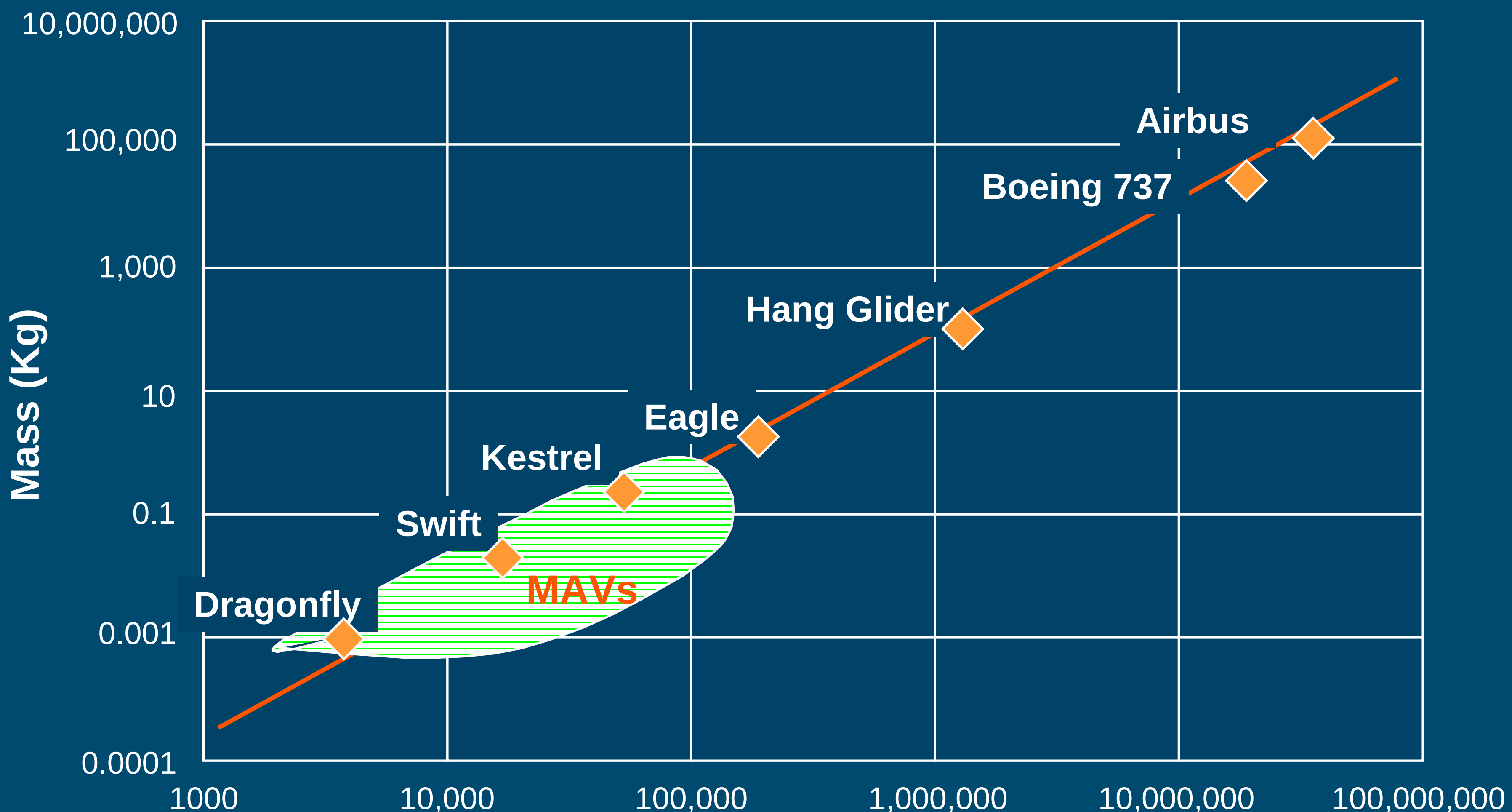
Postscript !
Do we want to go smaller ?

We can probably work in these :

But what about these ?



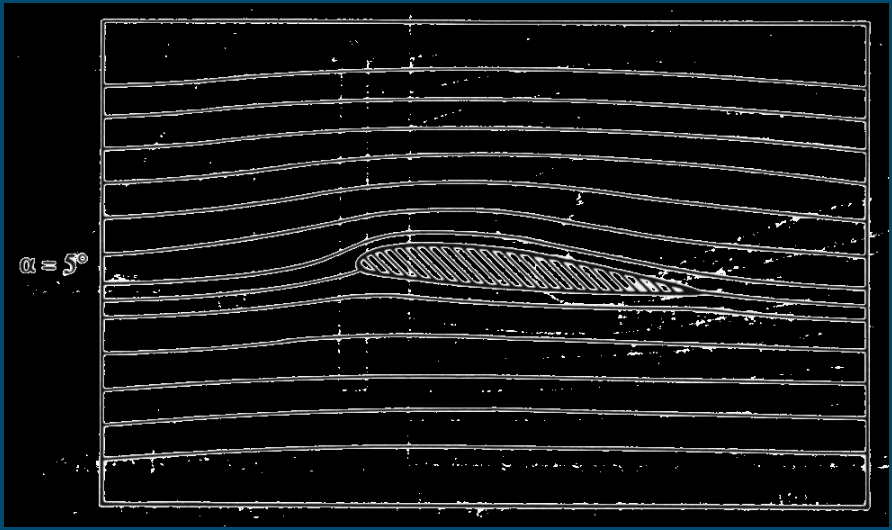
Reynolds Number



Aerodynamic flow

High Reynolds number

$\sim 10^7$



Low Reynolds number

$<10^4$

University of Oxford, Dept Zoology - Adrian Thomas & Graham Taylor

How small might we want to go ?

- Here is a highly integrated system
- Multiple sensors
- Highly integrated sensor, flight and trajectory control
- Reasonable ability to cope with environment (not 24/7)
- Energy efficient
- Relatively agile, excellent sense & avoid
- But flight regime is complex
- Would not want to emulate
- Could learn from nature though

If time permits show short video “dfly4slow” - 1 minute

Video courtesy of University of Oxford, Dept Zoology - Adrian Thomas & Graham Taylor