eBird – control of marine seismic streamers

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• PhD Engineering cybernetics, NTH 1994
  – 6 DOF control of autonomous underwater vehicles
  – Professor dr.ing. Thor Inge Fossen supervisor
  – Professor dr.h.c. Jens Glad Balchen advisor

• Principal Engineer R&D, Kongsberg Seatex 1994 - 2013
  – Seapath - Integrated GNSS/IMU navigation system for pos/vel estimation
  – MRU - Inertial sensor system for motion measurement and RPH estimation
  – eBird – Steering device system for positioning of towed streamer spread

• IPR Manager, Kongsberg Seatex 2014 – today
  – Coordination of and participation in all IPR activities
Marine seismic survey
Streamers need steering

Conventional operation
Worlds biggest controlled structure
eBird - Streamer steering device

• Mounted inline, low vibration noise
• Typically 300m separation
• Power and communication through streamer
• Wing profile optimized for maximum lift and minimum acoustic noise
• Batteries in wings → autonomous operation for several days
• 3 wings independently rotatable
• Decoupled roll, depth and lateral control
• Provides ~400 N at 4.5 kt through water
• 3 degrees feather angle
eBird body

- Length 370 mm Ø 74 mm titanium tube
- Inline mounting – stored on reel
- Sensors for roll angle and depth estimation
- CPU running bird local motion control loops
- Calculated wing deflection transferred to wings
- Wireless connections to wings
- 3 wing docking slots
eBird wing

• Attached/detached at deployment/retrieval
• Contains CPU, motor/gear and batteries
• Shaft coupling for motor/gear protection
• Wireless power/comms
• Batteries charged in sea in normal operation
• Provides power to body when loss of streamer power
• Stored in charging station onboard vessel
Wireless connection body-wing

- Wireless connection between body and wing
- No electrical parts exposed to water
- Easy snap on/off mechanism
- Identical iron cores surrounded by coils in body and wing

- Inductive energy transfer utilizing electro-magnetic resonance
- Radio communication: connector = antennae
- Two-way power and communication
- Back-deck operations: body and wing operated using hand-held radio-unit
Challenges

- Robust control - sea current, waves, objects in sea
- Low acoustic noise – wing profile
- Power distribution over 10 km – voltage drop
- Noise free power – constant load
- Noise free communication – modem
- Loss of power/comms – autonomous operation
- Multicomponent interactions
Hydrophone RMS noise

Conventional bird

Bird

No bird

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How many eBirds in one flock?
There have been issues..
Lift envelope

Clever choice of roll angle reference will enhance stability capacity
Control system

- Pos ref
- Pos control
- LatForce ref
- Roll ref
- Roll control
- Torque ref
- LatForce ref
- Control allocate (priority)
- Wing control
- Bird and streamer dynamics
- VertForce ref
- Depth ref
- Depth control
- Depth meas (abs pressure)
- Pos meas (AcuWing)
- Roll meas (accelerometers)
Robust control
Rapid depth change

Depth [m] and lateral force [%] step response at 4.5 kt

Time [sec]
Lateral control
Feather angle capability: $>3^\circ$

100% lateral force portside
300 m inline separation
eBird – The movie
AcuWing

- Acoustics integrated in eBird wing = AcuWing
- Bi-directional acoustic transducers in wing tip
- Acoustic source attached to stabilized platform
- Cross-line and in-line range measurements
Magnetic compass

- Heading estimation from 3-axis magnetometer
- Located in wing tip - redundancy
- Magnetic field compensation:
  - wing angle
  - wing slot position
  - roll and pitch
- Calibration in 3-axis Helmholz coil
- Algorithms for bird magnetic signature estimation
PosWing

- GNSS receiver and antenna in wing
- GNSS-wing pointing up in surface mode
- Ephemerides and clock aiding for fast acquisition (5-10 seconds)
- In combination with
  - AcuWing → sound speed calibration
  - Compass → streamer shape
  - Inertial sensors → integrated filter
  - Radio → aiding data or differential corrections
- No need for tail buoy, fully submerged streamer spread
- Easy to find from work-boat
Thank you for your attention!