UAV activities at
Center for Autonomous Marine Operations and Systems
Department of Engineering Cybernetics, NTNU

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Outline
• Our UAV research visions and strategy
• Our UAV platforms and research infrastructure
• Current UAV-related research topics and short-term plans
One of the main AMOS visions

Coordinated autonomous marine operations involving UAS together with marine surface and underwater systems

Oceanography, environmental monitoring, oil spill response, inspection of fisheries, ice monitoring, search and rescue, science and climate research, situation awareness, communication relaying, survey and mapping, ship traffic monitoring, inspection of fish farms, offshore wind parks and other assets.
Our overall UAV Research strategy

UAV Platform -> Data -> Information -> Action

Open architectures research platform and in-house system integration capability!

Sensor-based guidance and navigation
Real-time data processing and sensor fusion
Cooperative control and networking
Interaction with the environment, manipulation

Fault tolerance and robustness in maritime and arctic environments
Anti-icing
Autonomous marine launch and recovery
Robust navigation
Robust communication
Flight control
Detect and avoid, transponders
Airframe
Power and propulsion
UAV Factory Penguin B w/ Piccolo SL

- 28 m/s cruise speed
- Gasoline, 8 hr endurance
- MTOW 21 kg
- 2-5 kg payload capacity
- Large payload bay
- 80W generator
- Avionics system integration made with Maritime Robotics based on Cloudcap technology
- Telemetry on 2.4 GHz radio, GPRS (and VHF)
- Catapult launch
- Custom payload system integration with avionics interface
Skywalker X8 w/Ardupilot

- 18 m/s cruise speed
- Catapult launch
- Belly or net landing
- Electric, 1hr endurance
- Large payload bay
- >1 kg payload capacity
- Inexpensive
- Flexible avionics and payload system integration with ArduPilot open source autopilot and mission planning SW
- Currently telemetry on 433 MHz or 5.8 GHz radio for VLOS
- Can be set up for BLOS with GPRS and VHF radio links
3DRobotics hexa-copter w/Ardupilot

- Electric, 5-10 min endurance
- 1 kg payload capacity
- Inexpensive
- Flexible system integration with Ardupilot open source autopilot and mission planning SW
- Telemetry on 433 MHz og 5.8 GHz radio
Microdrone Quad-copter

- Electric, 45 min endurance
- 2-3 kg payload capacity
- Turn-key solution
- Various camera, video and radio systems
Field experimental capabilities

Currently
- Jointly with Maritime Robotics
  - Eggemoen (VLOS, EVLOS)
  - Ørland (BLOS)
  - Breivika, Agdenes (VLOS, under upgrade to BLOS)
- Multi-rotor «cage» at NTNU
- Field near Trondheim for VLOS operations

Under preparation
- R/V Gunnerus
- Mobile «on demand» operations center
Five focused main research areas

- Smart UAV remote sensing payloads - Autonomous detection, identification and tracking of objects and distributed features
- Robotic UAV payloads – Deployment and recovery of ground/floating sensor nodes from UAV
- Multi-vehicle networking – mobile sensor network
- Fault-tolerant and robust UAV navigation
- Enabling ship-based UAV operations in remote and harsh conditions

In addition there are several other UAV-related activities.
Smart Payloads - Autonomous Detection and Tracking of Objects and Features

Want to reduce the need for high-capacity payload datalink and ground analysis by onboard intelligence and autonomy

- Real-time onboard machine vision
- Sensor-based autonomy
- Mission planning for search based on optimization
- Distributed features such as oil spills and sea ice
- System integration
Robotic Payloads -
Deployment and recovery of ground/floating sensor nodes from UAV

- Modular and smart floating sensor nodes
- Multi-rotor UAV payloads for autonomous field deployment and recovery of small objects
- Fixed-wing UAV payloads for field deployment and recovery of small objects
- Data acquisition from buoys, AUVs and other floating assets with insitu sensors using UAVs
Multi-vehicle Networking

- System integration with DUNE/NEPTUS middleware
- Inter-operability with aerial, surface and underwater sensor systems and vehicles
- Delay-tolerant and ad.hoc. networking (radio and acoustic)
- Onboard mission planning and re-planning (T-REX, from MBARI)
Fault-tolerant and robust UAV navigation

Want to provide accurate, redundant and robust low-cost global navigation solutions, e.g. when GPS and compass fails:

- Automatic airspeed sensor fault detection and diagnosis
- Camera-based odometry and optical flow as an alternative to magnetometer
- Image-based navigation at sea (wave direction recognition)
- MEMS-based inertial navigation for navigation aiding, north seeking and dead reckoning
  - Standalone
  - Integrated with mathematical vehicle model
  - Integrated with camera-based systems
  - Other combinations

Accurate and reliable local navigation for precision tasks
- camera, inertial, laser/LIDAR, radar, RTK/DGPS (moving baseline) for autonomous launch/recovery, tracking, docking, pick-up and delivery
Enabling ship-based UAV operations in remote and harsh conditions

- **Launch and recovery of fixed-wing UAVs from moving ships**
  - Low-cost autonomous ship-based net recovery systems for fixed-wing UAVs based on RTK/DPGS and local navigation
  - Advanced recovery net for larger UAVs (joint research with Maritime Robotics)
  - Low-speed recovery of larger UAVs with moving ship rendezvous
- **Integration with ship and air surveillance systems (e.g. AIS, ADS-B and marine surface search radar) for situation awareness**
- **Small UAV inflight anti-icing and de-icing systems**
  - Fault-detection and identification for early warning; identification of icing (versus faults related to airspeed sensor, engine/fuel system, servos, etc.)
  - Inflight anti-icing and de-icing based on conductive coating (electric power); smart power control system design
  - Fault-tolerant flight control in degraded conditions
- **Long-distance radio communication and networking**
  - Phased array antennas
  - Robust heterogeneous radio communication and network technologies
Concluding remarks

Our strategies and objectives are defined on a «More than 10 year» perspective

- Build world-leading fundamental knowledge to extend state-of-the-art
- Close collaboration with industry and stakeholders
- Participate in technology demos and challenging pilot projects with end users
- National and international partnerships and collaboration with strong groups
- Investment into infrastructure, equipment and own operational capacity
- Focus on research platform with open architectures that allows own system integration and extentions on top of state-of-the-art systems
- Currently about 15 researchers/PhD fellows, and 20 master students working more or less full time on this UAV activity at NTNU