Design and Navigation of Flying Robots

Roland Siegwart, ETH Zurich
www.asl.ethz.ch

Drones:
From Technology to Policy, Security to Ethics
30 January 2015, ETH Zurich

ASL – ETH Zurich

- Micro Air Vehicles

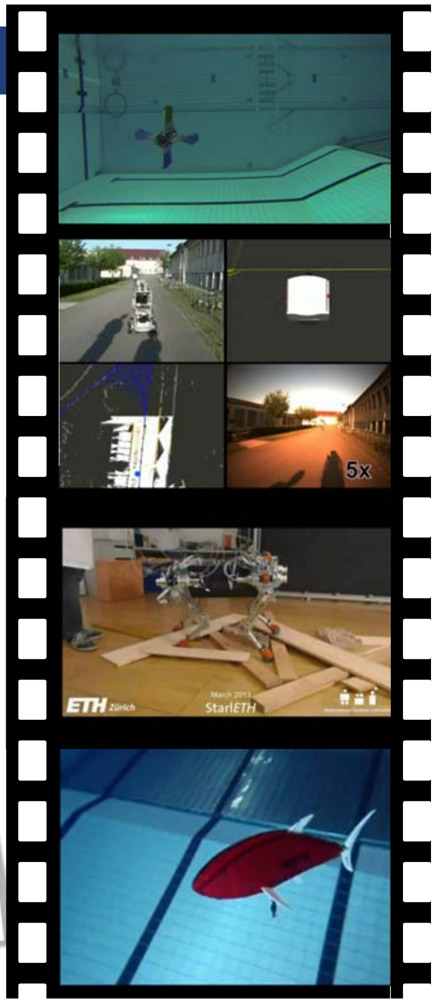
- Walking and Running Quadruped Robots

- Service Robots

- Autonomous Robots/Cars for Inner City Environments

- Inspection Robots
- Space Robots for Planetary Exploration

- Swimming Robots



UAV (Unmanned Aerial Vehicles) | flight concepts

- Helicopters:
  - < 20 minutes
  - Highly dynamic and agility

- Fixed Wing Airplanes:
  - > some hours; continuous flights possible
  - Non-holonomic constraints

- Blimp: lighter-than-air
  - > some hours (dependent on wind conditions);
  - Sensitive to wind
  - Large size (dependent on payload)

- Flapping wings
  - < 20 minutes; gliding mode possible
  - Non-holonomic constraints
  - Very complex mechanics

Festo BionicOpter

UAV | potential applications

- Search and rescue, surveillance

- Industrial inspection
- Agriculture, mining and construction

- Next generation satellites
- …

UAV | requirements

- Appropriate flight concept
  - Power autonomy
  - Agility
  - Robustness
- Navigation with on-board sensing and processing
  - Robustness against communication and GPS loss
  - “home” button
- Simple and intuitive operation
  - Stable on “hands-off”
  - Collision avoidance and localization / SLAM

UAV | requirements

- Appropriate flight concept
  - Power autonomy
  - Agility
  - Robustness
- Navigation with on… and processing
  - Robustness a… on and GPS loss
  - “home” b…
- Si… ive operation
  - …ands-off”
  - … avoidance and localization / SLAM

Teleoperation or GPS only navigation will, for most applications, not do the job

EU – Projects | Unmanned Aerial Systems

Search and Rescue
Transportation

(Industrial) Inspection
Agriculture

NIFTi, TRADR, sfly, ICARUS, SHERPA, mycopter, AIRobots, European Robotics Challenges, Flourish, AERO WORKS

ETH zürich ASL Autonomous Systems Lab

Scaling Down of Helicopters

OS4 - 2003

70 cm
650 g

CoaX - 2005

30 cm
200 g

muFly - 2007

10 cm
50 g

Visual - Inertial SLAM | cheap and available

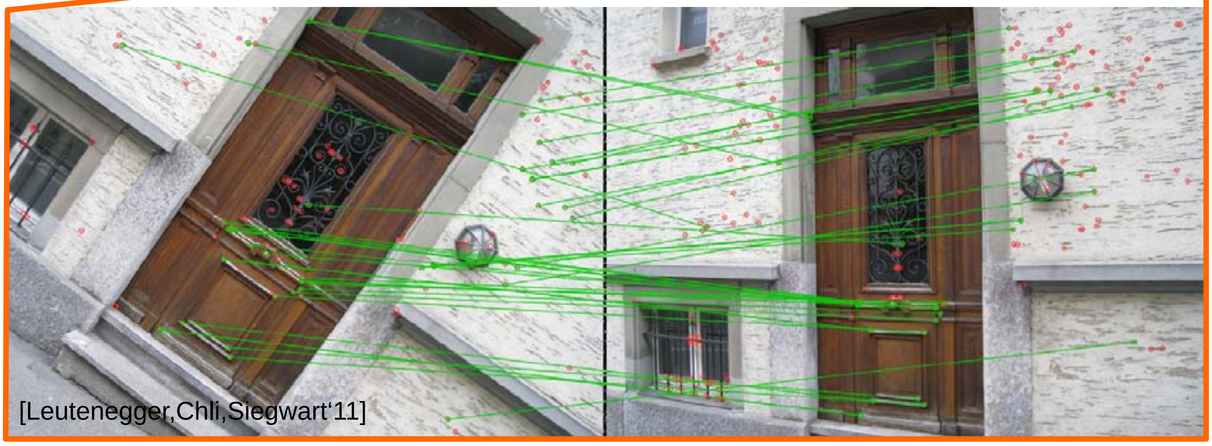
ADIS166448

- Strong short-term temporal pose constraints

+

IDS uEye

- Spatial relative pose constraints
- Information on structure



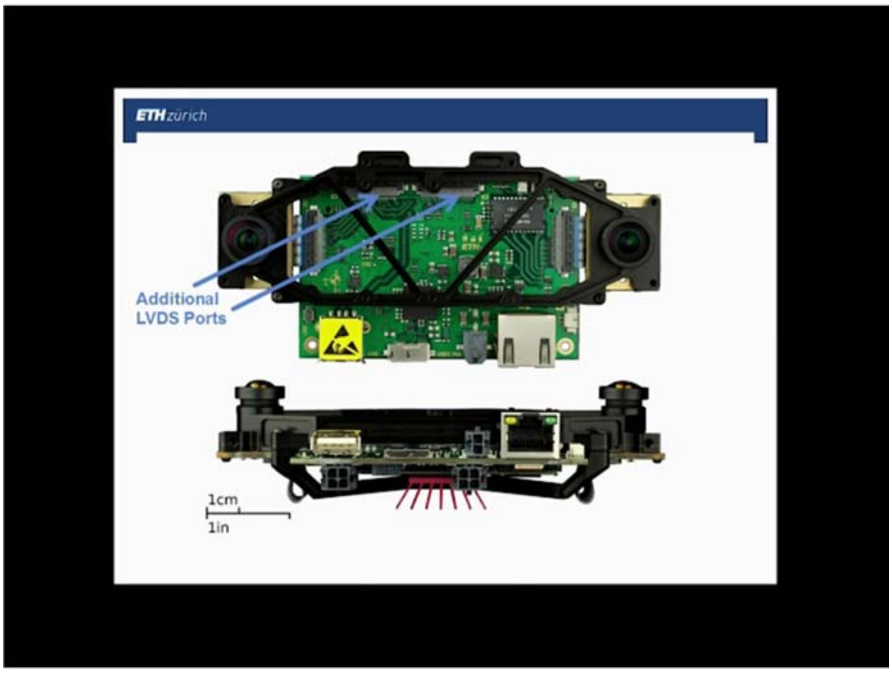
[Leutenegger,Chli,Siegwart'11]

UAV | Vision only navigation

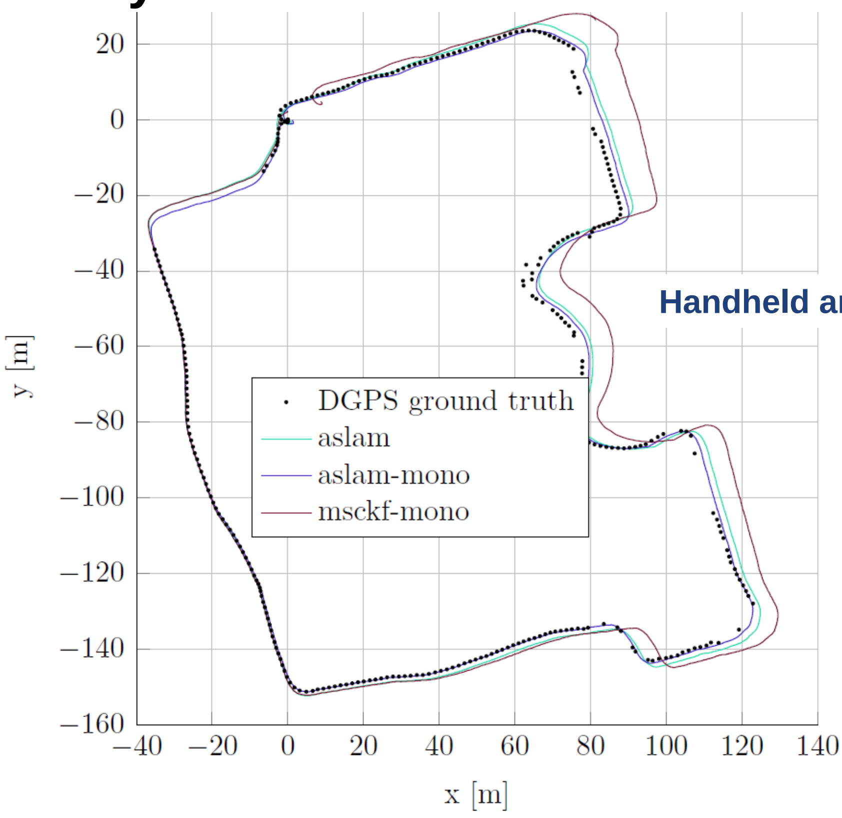
www.sfly.ethz.ch/

- Swarm of small helicopters
  - Vision only navigation (one camera, GPS denied)
  - Fully autonomous with on-board computing
  - Feature-based visual SLAM
    - robust against lighting changes and large scale changes

A Synchronized Visual-Inertial Sensor System with FPGA Pre-Processing for Accurate Real-Time Slam



Keyframe VIO with Online Extrinsics Estimation



Handheld around ETH

MSCKF: visual-inertial stochastic cloning sliding-window filter (Mourikis et al., 2009).

UAV | collision avoidance and path planning

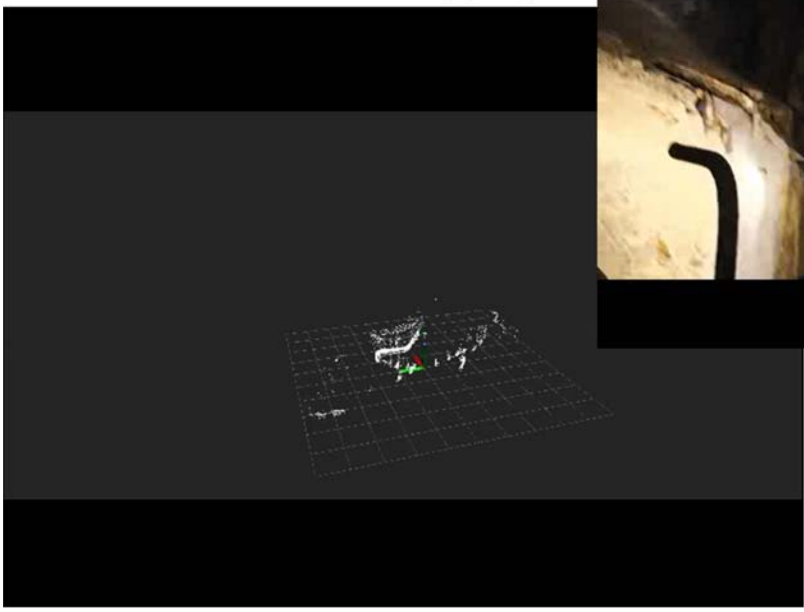
- Real time 3D mapping (on-board)
- optimal path planning considering localization uncertainties

UAV | facade scanning and 3D reconstruction

- Enhanced teleoperation or autonomous operation
- Visual-inertial localization for optimal 3D reconstruction

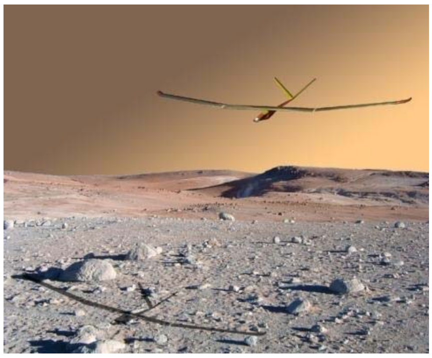
UAV | 3D mapping in mines

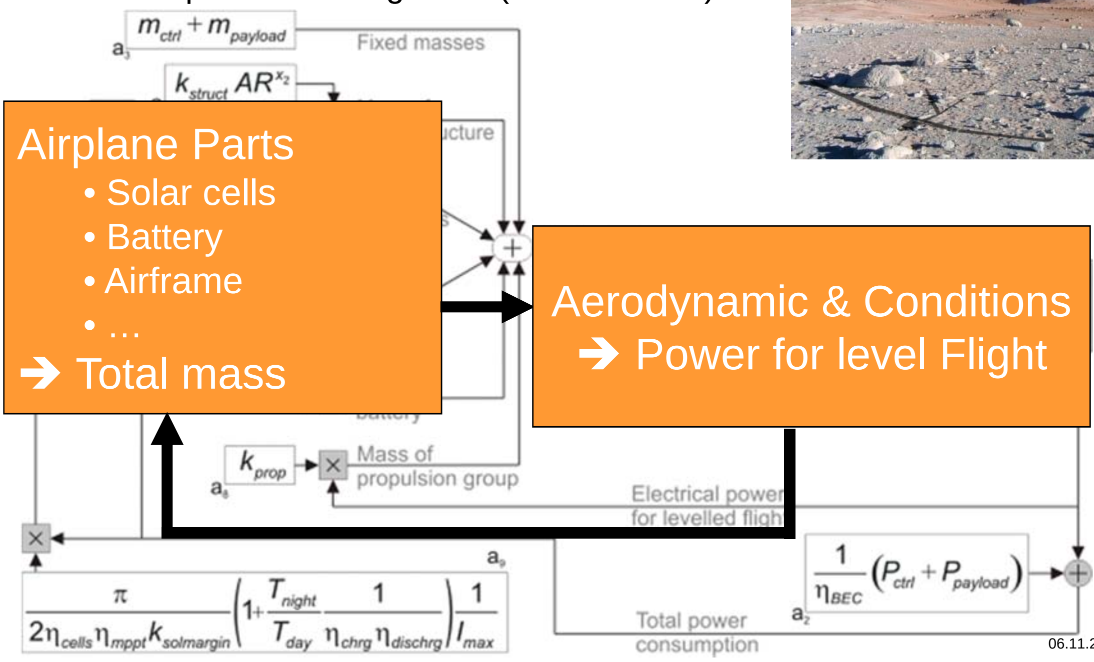
- Vision-based localization and SLAM
- Laser-based 3D mapping



Solar Airplane |
design methodology for continuous flights

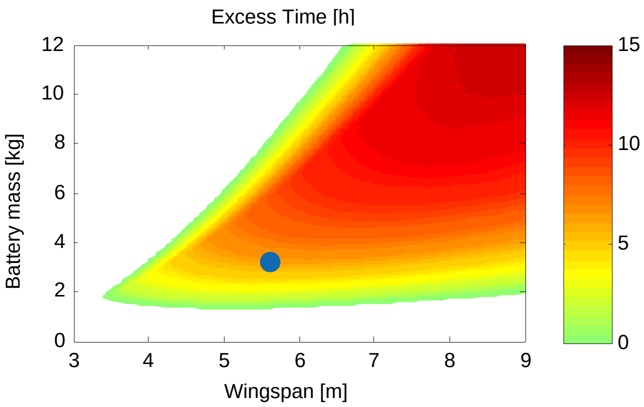
- Based on Mass & Power Balance
  - Need for precise scaling laws (mass models)





Solar Airplane | Optimization

- Design space at 38° N, June 21st
  - Fixed Aspect Ratio: 18.5



  - Flat optimum at wingspan 11.5 m

- Chosen *AtlantikSolar* configuration:
  - Wingspan 5.65 m
  - Battery mass 2.9 kg
  - Structural weight
    - Predicted: 1‘317 g
    - Effective: 1‘800 g
    - Prediction [Noth’08]: 4‘638 g

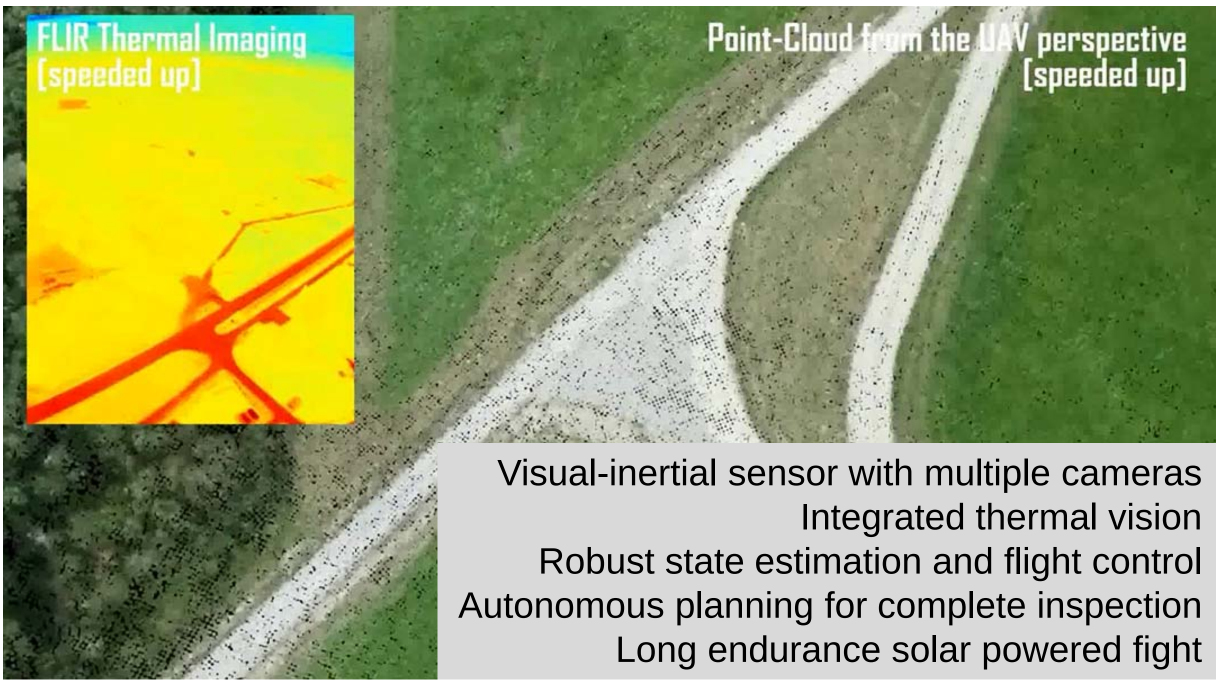
Solar powered fixed wing airplanes: Long duration / continuous flights

senseSoar
- Wingspan: 3 m
- Wing area: 0.725 m2
- Peak Solar power 140 W
- Power Consumption 50 W
- Masses:
  - Overall: 3.72 kg
  - Batteries: 1.89 kg
- Nominal Speed 10 m/s
- Sensors
  - Air speed
  - IMU
  - GPS
  - Camera
  - **IR camera**

AtlantikSolar
- Wingspan: 5.64 m
- Solar area: 1.5 m2
- Peak Solar power 280 W
- Power Consumption 40 W
- Masses:
  - Overall: 6.2 kg
  - Batteries: 2.9 kg
- Nominal Speed 10 m/s
- Sensors
  - Air speed
  - IMU
  - GPS
  - Camera

Atlantik Solar | crossing the Atlantic in summer 2015

Solar Airplane | visual navigation



ASL Team