Design and Navigation of Flying Robots

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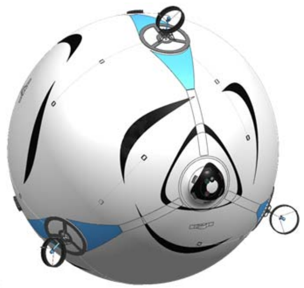
FLYNET 2014
Micro and Nano Aerial Vehicles Networks for Civilian Use
November 3-5, 2014, ETH Zurich

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… …and processing
  - Robustness a… …on and GPS loss
  - "home" b…
- S… …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

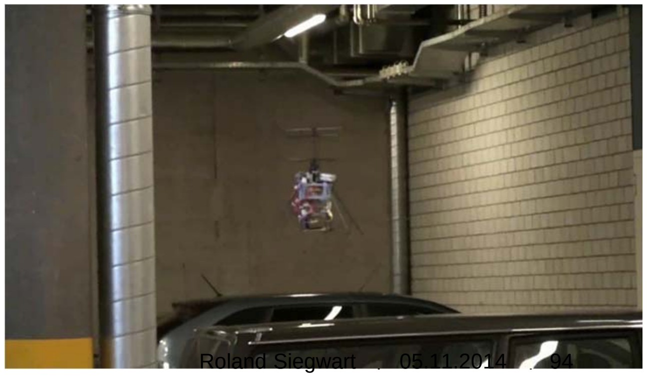
NIFTi
TRADR
sfly
ICARUS
SHERPA

(Industrial) Inspection

AIRobots
European Robotics Challenges

Scaling Down of Helicopters

OS4 - 2003	CoaX - 2005	muFly - 2007
		
70 cm 650 g	30 cm 200 g	10 cm 50 g



Visual - Inertial SLAM | cheap and available

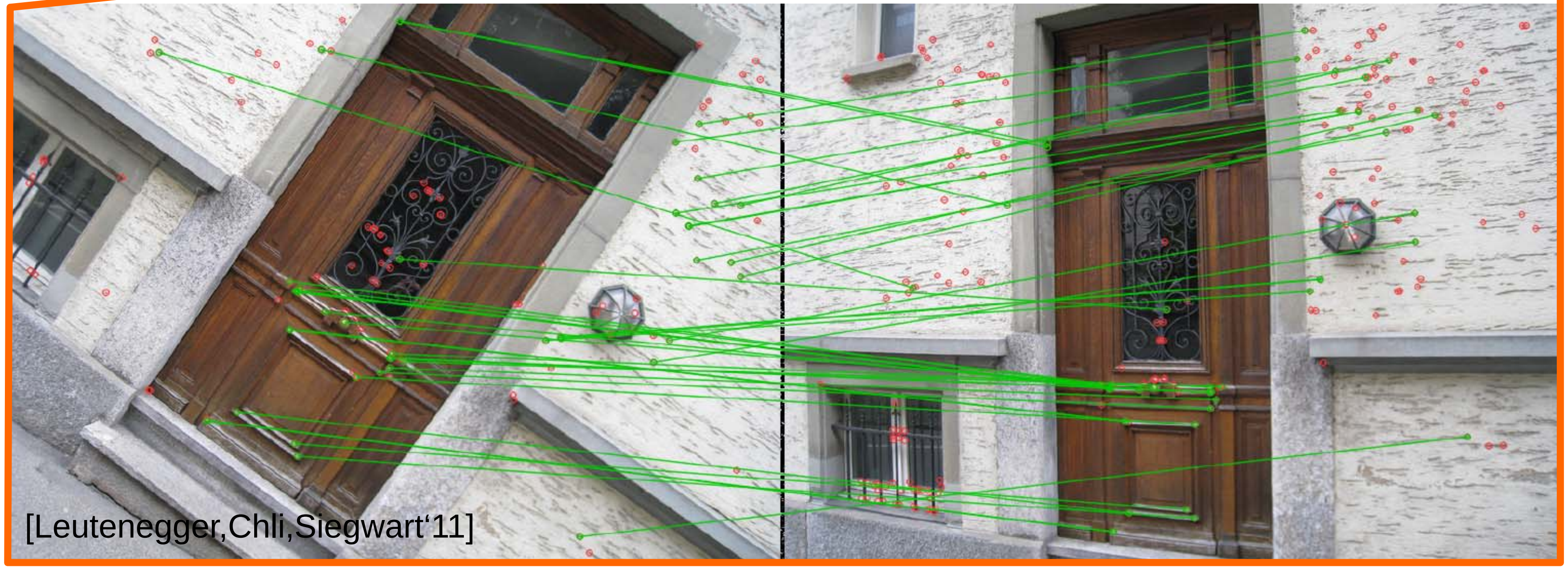
ADIS166448

- Strong short-term temporal pose constraints

+

IDS uEye

- Spatial relative pose constraints
- Information on structure



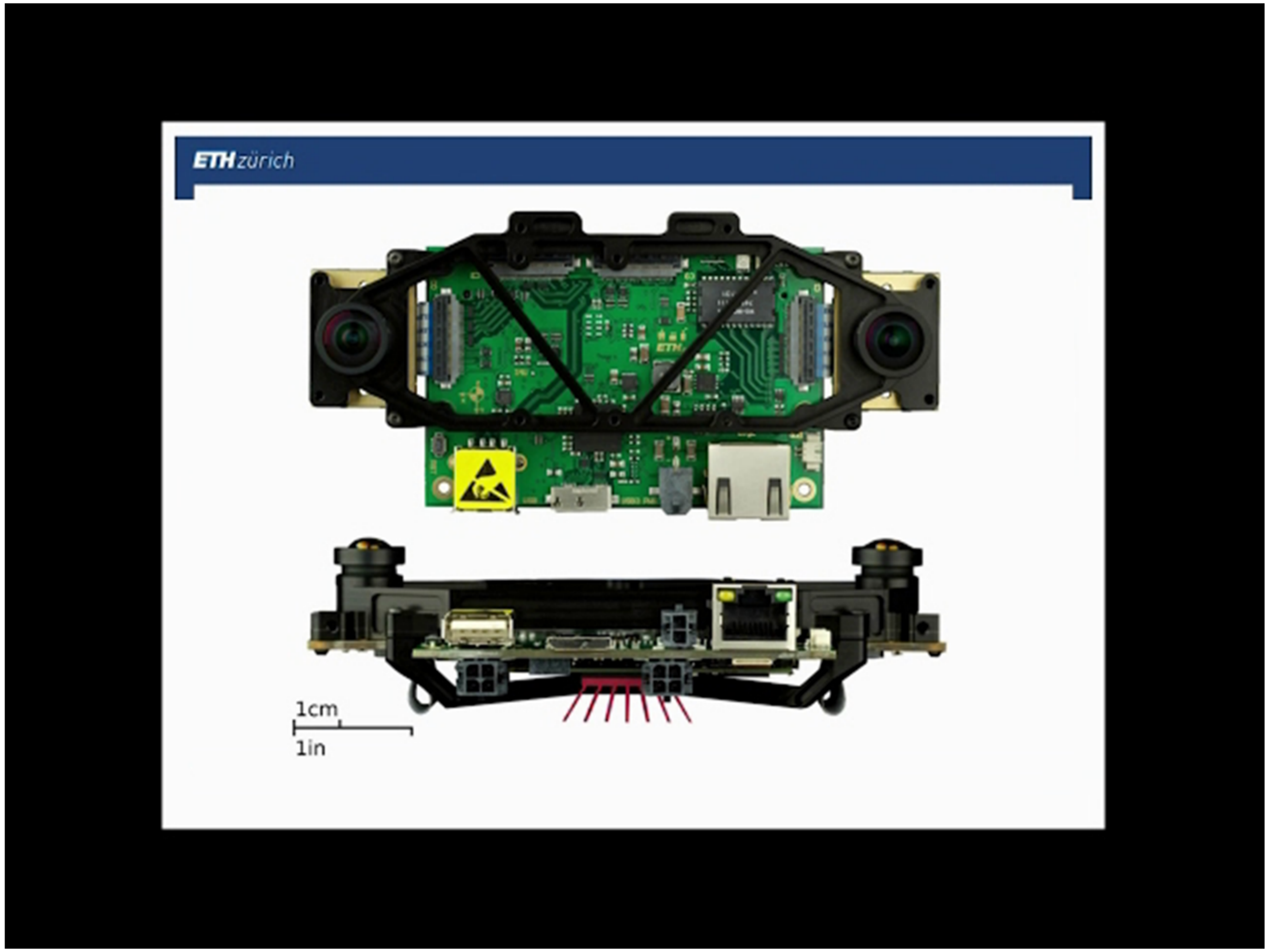
[Leutenegger,Chli,Siegwart'11]

www.sfly.ethz.ch/

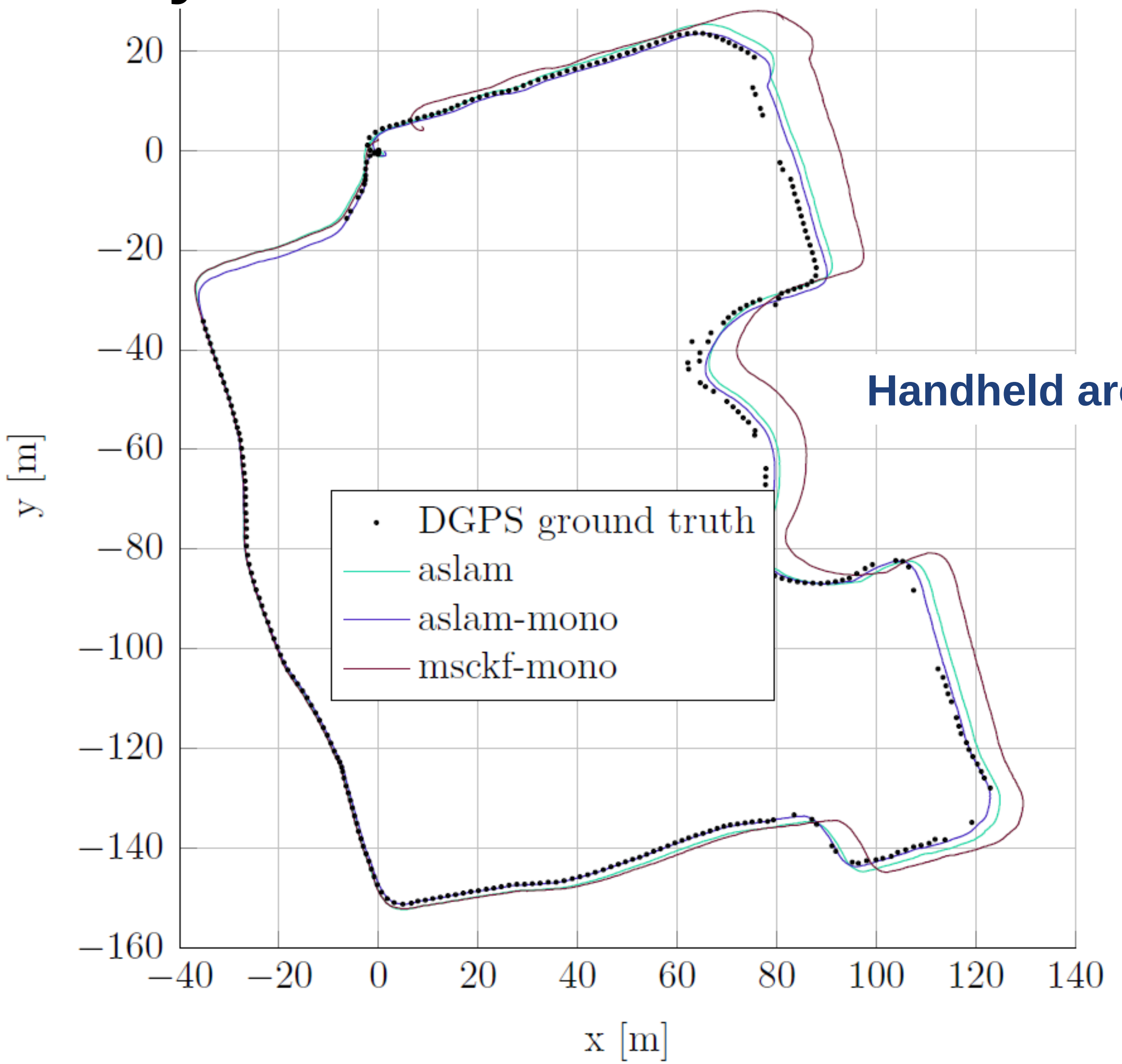
UAV | Vision only navigation

- 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

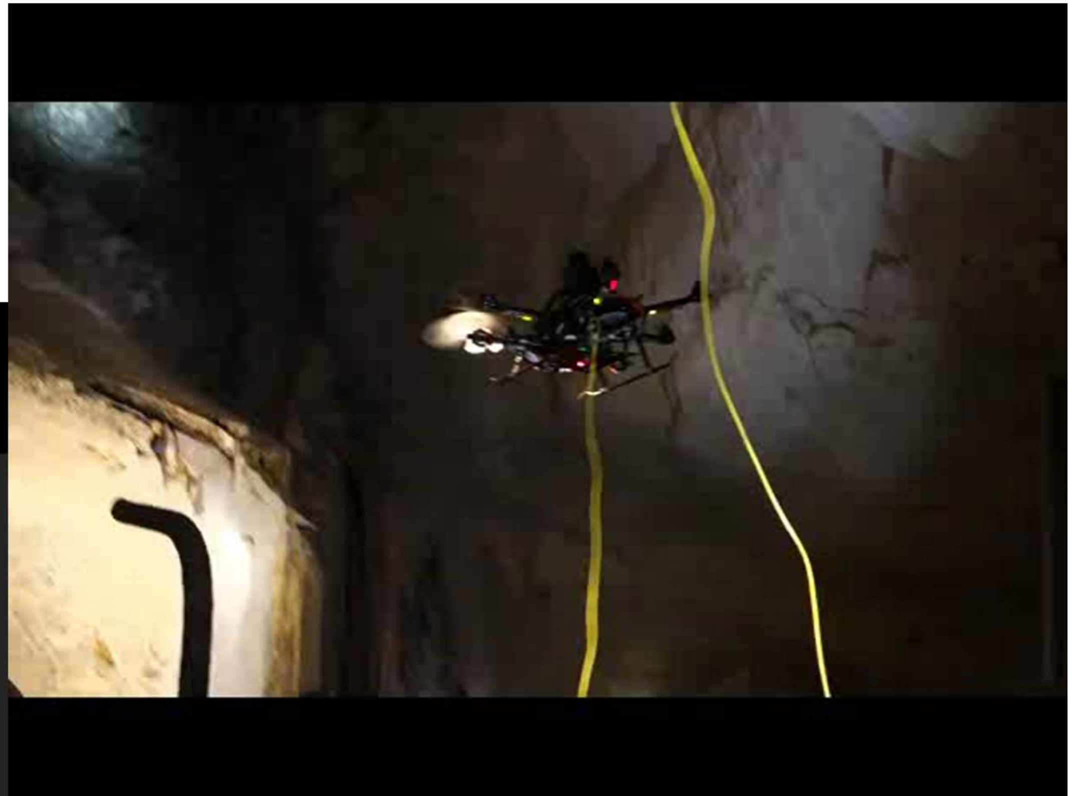
- Real time 3D mapping (on-board)
- optimal path planning considering localization uncertainties

UAV | facade scanning and 3D reconstruction

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

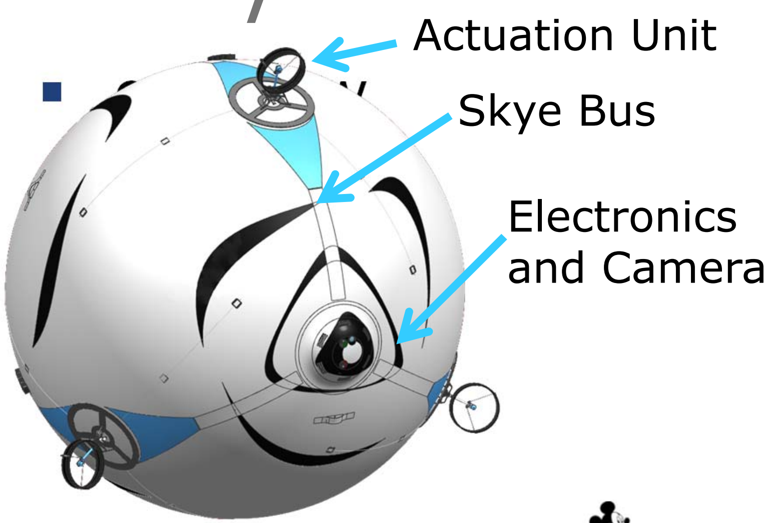
UAV | 3D mapping in mines

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

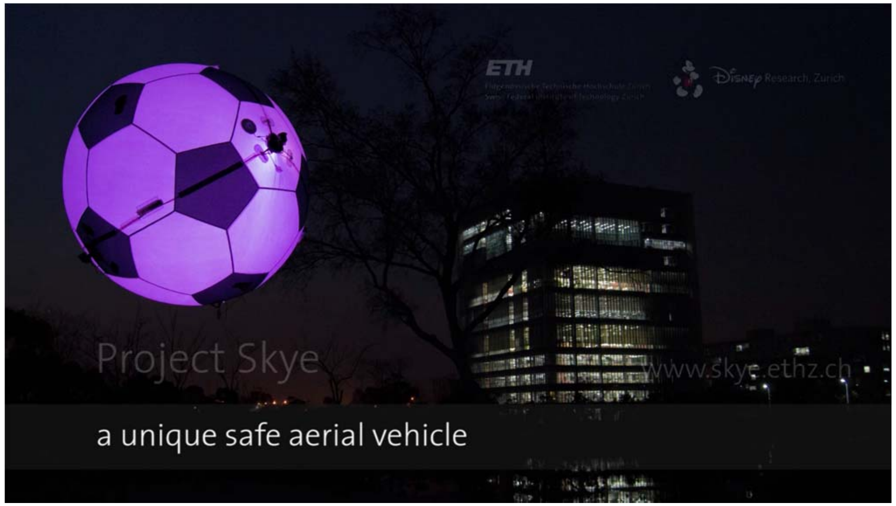


skye an omnidirectional, spherical aircraft

www.projectskye.ch/



Disney Research, Zurich

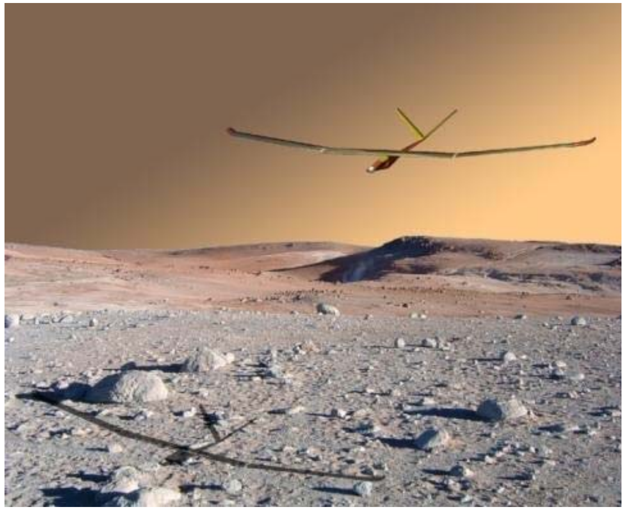


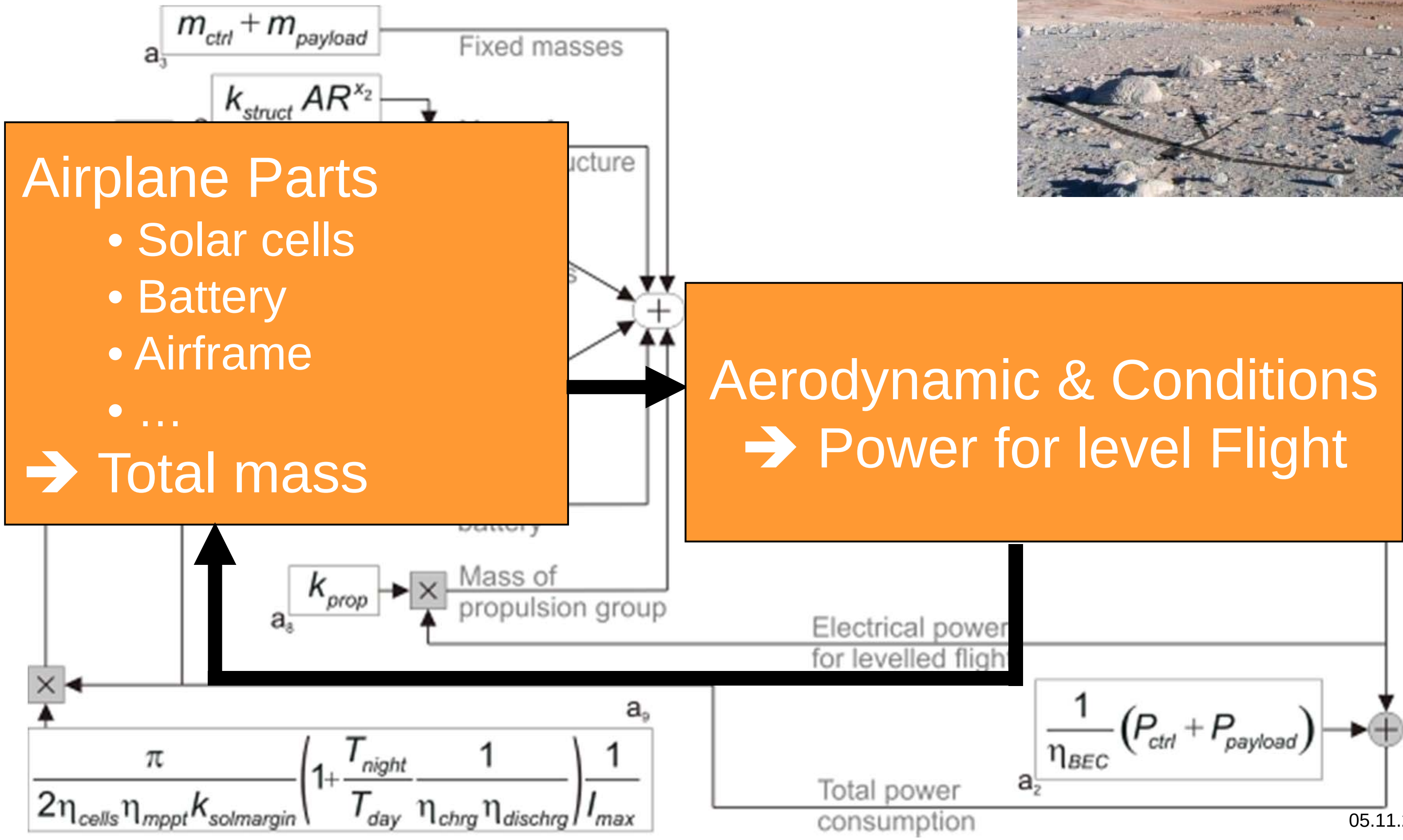
Total Weight	9.818 kg
Actuation Units (4x)	2.737 kg
Electronics and Power	2.706 kg
Hull	3.650 kg
Pressure Elements	Ca. 0.150 Kg

Buoyancy	Ca. 10 kg
Diameter	Ca. 2.7 m
Volume	Ca. 10 m^3

Solar Airplane |
design methodology for continuous flights

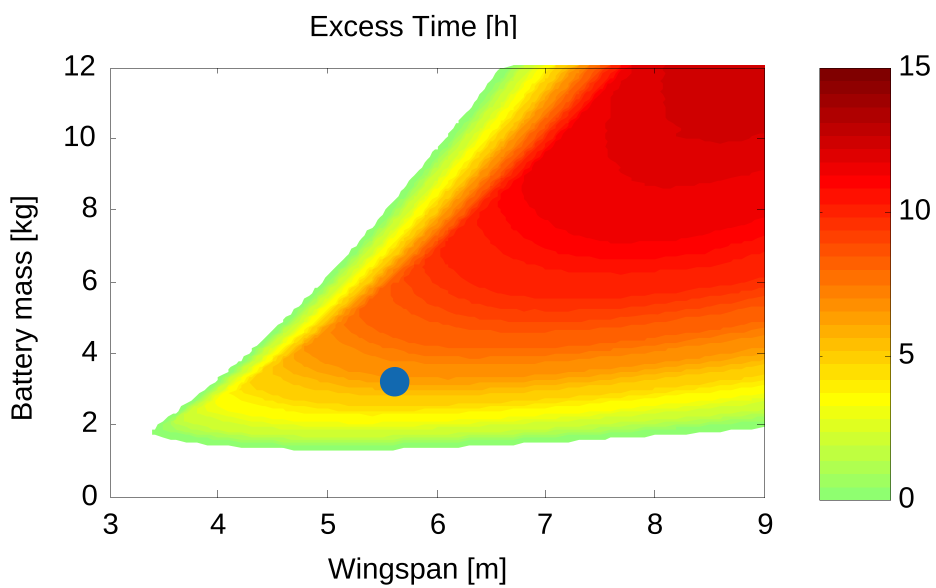
- Based on Mass & Power Balance
  - Need for precise scaling laws (mass models)





Solar Airplane | Optimization

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

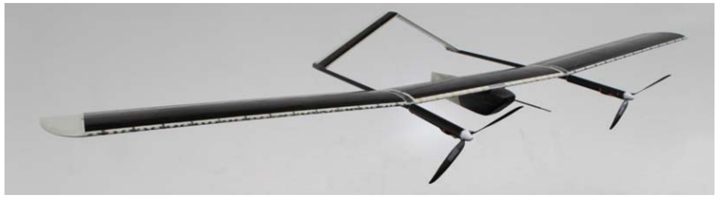


  - Flat optimum at wingspan 11.5 m

- 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



senseSoar

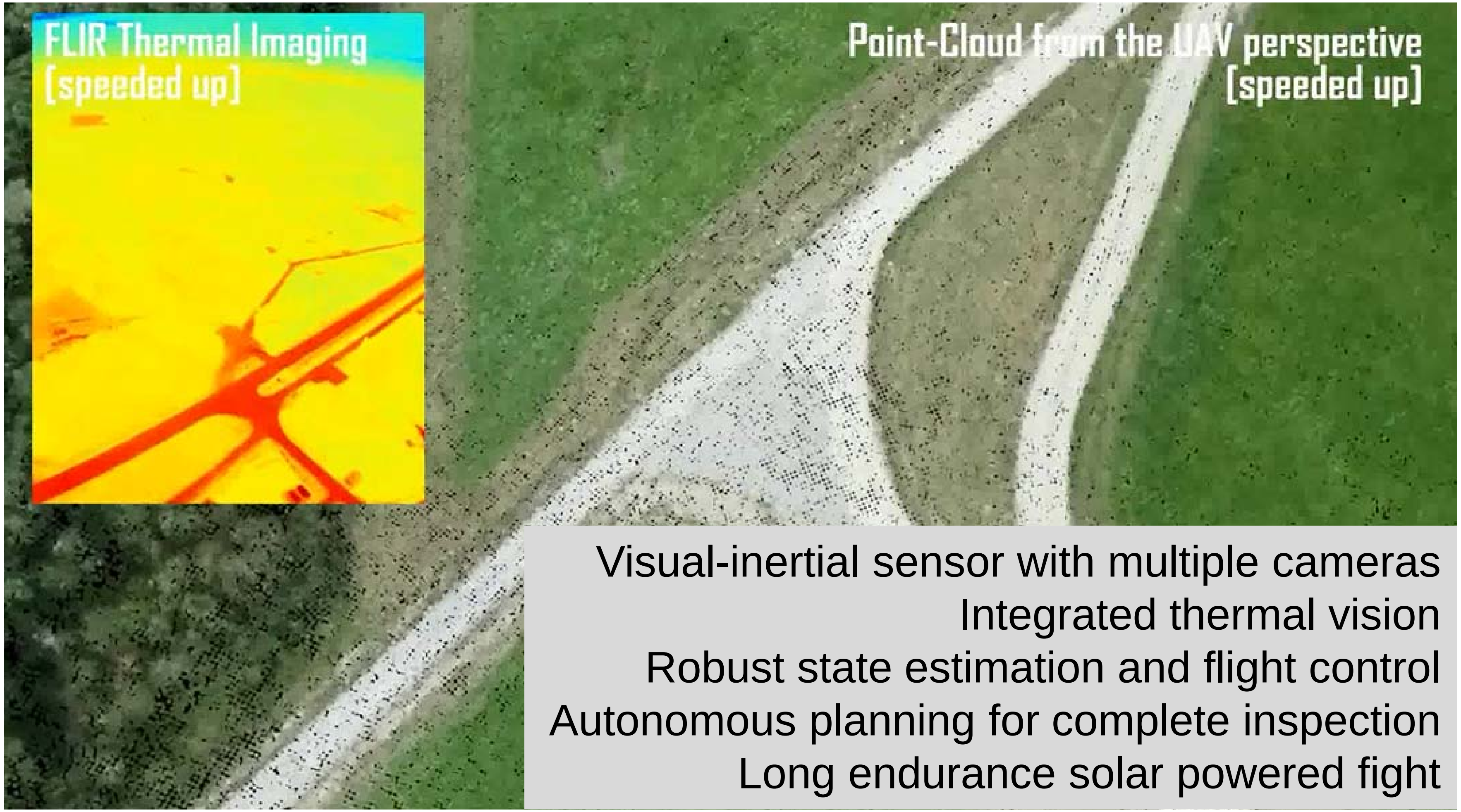
- Wingspan: 3 m
- Wing area: 0.725 m2
- Peak Solar power 140 W
- Power Consumption 50 W
- Masses:
  - Overall: 3.72 kg
  - Batteries: 1.89 kg
- Nominal Speed 10 m/s
- Sensors
  - Air speed
  - IMU
  - GPS
  - Camera
  - **IR camera**

AtlantikSolar

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: 1.89 kg
- Nominal Speed 10 m/s
- Sensors
  - Air speed
  - IMU
  - GPS
  - Camera

Solar Airplane | visual navigation



Visual-inertial sensor with multiple cameras
Integrated thermal vision
Robust state estimation and flight control
Autonomous planning for complete inspection
Long endurance solar powered fight

AtlantikSolar | crossing the Atlantic in summer 2015

ASL Team