Robust launching and landing for soft wing AWE systems

AWESCO internal research review, IMTEK University of Freiburg

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Introduction

- B.Sc. and M.Sc. in Aerospace Engineering from TU Munich
    - Focus on flight control and flight physics
- Since January 2016 PhD student at TU Delft

The challenge

Important characteristics of the launching and landing system

- Safety
- Availability
- Reliability

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- Performance
- Autonomy
- Ecological footprint

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- Derivation of system requirements
- Goal: Achieve economic feasibility of a new and complex technology

Categorization of launching and landing systems

- **On-board propulsion** (TwingTec, Kitemill, Makani):
  - Generate thrust in flight direction and use wing to generate the lift (HTOL)
  - Generate directly the lift force (VTOL)

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- **Aerostatic** (balloons, zeppelins,...)
- **UAVs**

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- **Static or telescopic mast** (TU Delft, SkySails)
- **Rotating arm** (Enerkite, Kitegen)
- **Catapult, Slide, Winch** (Alula Energy, Ampyx, ABB)

Static mast configuration

- Kite is hanging upside down
- If the wind is strong enough the kite lifts itself

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- Simple
- Cheap and easy to install
- No external energy source required

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- Strong dependence on wind speed and wind direction
- Possible collision of kite with mast/suspension lines
- Launch only in one direction
- Difficult to predict the reliability + availability

Ref.: Haug S.: Design of a Kite Launch and Retrieval System

Prototype for mast configuration

- Kite is hanging upside down

1

Ref.: Haug S.: Design of a Kite Launch and Retrieval System

Prototype for mast configuration

- Wind lifts the kite...

2

Ref.: Haug S.: Design of a Kite Launch and Retrieval System

Prototype for mast configuration

- and tether is reeled-out.

3

Ref.: Haug S.: Design of a Kite Launch and Retrieval System

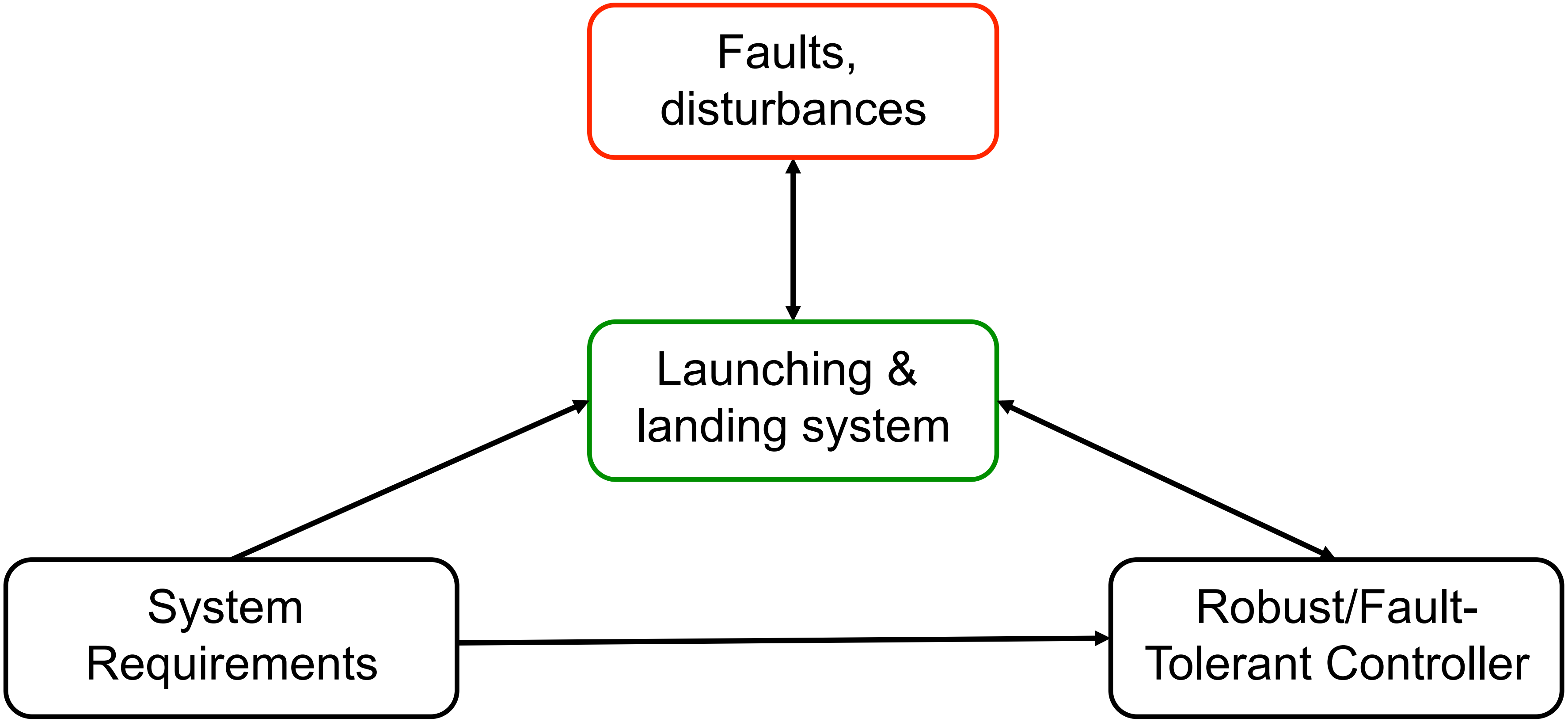
Approach

Development of a robust and fault-tolerant L & L concept

1. Identification of requirements for a robust/fault-tolerant L&L system
2. Selection of a concept that best satisfies the requirements
3. Analysis of possible failure modes and their effects (e.g. FMEA, FTA)
4. Development of a robust/fault-tolerant controller for the L&L system
5. Integrate L&L controller into existing kite simulator of TU Delft
6. Verify concept experimentally

Conclusion

- My research will consist of modeling/developing/analysing:



Overview secondments

- **SkySails**
  - May 2016, 1 month
  - Goal: Get familiar with automatic launch and retrieval
- **University of Freiburg**
  - August & September 2017, 2 month
  - Goal: Comparative analysis of control techniques

Thank you for your attention!

Any questions?

Backup slides

Possible control approaches

- **Passive fault-tolerant control**
  - H_∞ control
  - LQG control
  - ...
- **Active fault-tolerant control**
  - Adaptive control (MRAC, L1,...)
  - Disturbance-Observer-Based control
  - Linear-Parameter Variant control
  - Failure-Detection and Isolation + controller reconfiguration
  - ...

Choose control approach dependent on L&L <u>concept</u> and <u>requirements</u>

On-board propulsion

http://www.kitemill.no

- Used by e.g. Makani/Google, TwingTec, Kitemill
- Propellers are used to generate the lift for take-off

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- Independent of ground wind speed
- Launch and retrieval components are already installed in AWES operated in drag mode

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- Additional propellers required for AWES operated in lift mode
- Additional power supply
- Impact on aerodynamics

VTOL UAV based launch

- UAV is attached to the kite during the launch and lifts the kite to the operating altitude

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- Launch in an arbitrary direction is possible
- Short setup time
- No additional infrastructure
- Portability
- Launch of multiple kites with one launching system

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- Requires heavy payload lifting capabilities
- Controllability issues in presence of gusts
- Energy supply
- Autonomous attachment is difficult to achieve
- Complexity

Rotational launch

- Kite is connected to a rotating arm
- As soon as take-off speed is reached the tether/kite is released

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- Works also for low ground wind speeds (~1.5 m/s)
- Adjustable launch direction

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- Manufacturing costs
- Material costs
- Environmental impact
- Installation costs + compexity

Ref.: Geebelen, K. et al: An experimental test set-up for launch/recovery of an AWE system, 2012.
http://www.kitegen.com, http://www.enerkite.de

Catapult launch

- Used by e.g. Alula Energy
- System is accelerated using a winch/linear motor
- Small on-board propellers may help to climb to the operation height

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- Less dependent on ground wind speed

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- Required infrastructure
- Rotational platform for adjustable launching direction required

Telescopic mast

- Used by SkySails
- Telescopic mast lifts kite to a certain altitude
- Wind inflates the kite

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- Robust concept due to its simplicity
- Storage included

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- Strong ground wind speed is required or a high mast

http://www.skysails.info