Automatic control at Saab Aerosystems

Problems, solutions and perhaps some adaptivity?

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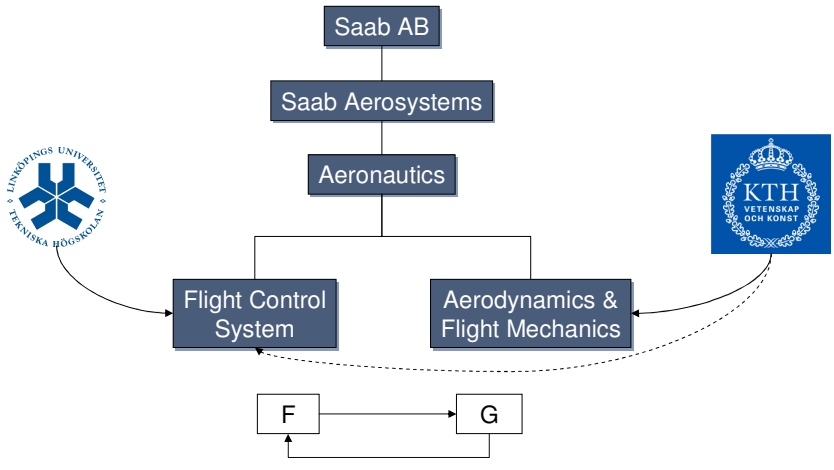
Organization



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Aircraft

JAS 39 Gripen

Sharc

Filur

Skeldar V-150

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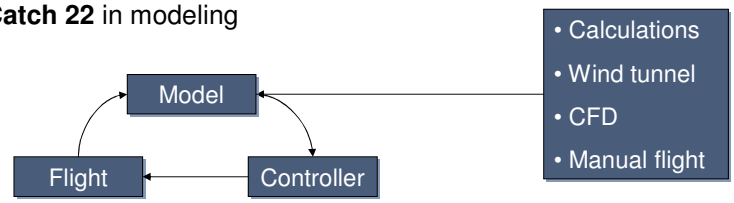
Flight control design

- **All** aircraft are **unstable**

Def: Instability = without control, it doesn't work

- **Catch 22** in modeling



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Flight control design

- Plenty of **sensors**
  - Simplifies modeling
  - Enables state feedback
- Flying is **not** a regular part of the design loop
- **Clearance** is mainly done using **batch simulations**

The model is powerful!

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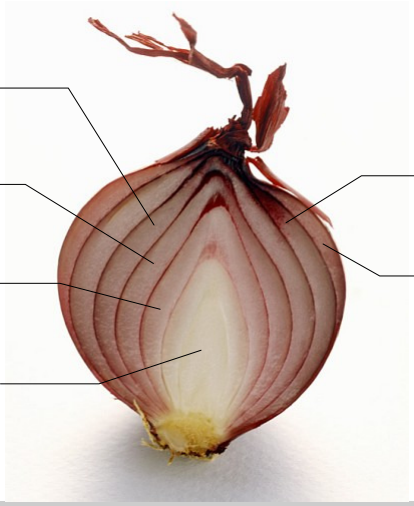
Control design strategy



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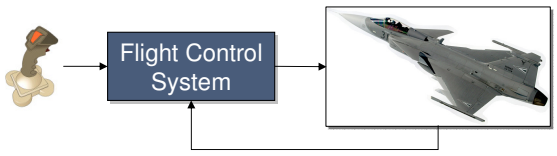
JAS 39 Gripen



The FCS should...

- **Stabilize** the aircraft
- Give desired **handling qualities**
- Make the aircraft "**care free**"

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Dynamics

- The **aircraft dynamics** depends on:

  altitude × speed × aircraft type × fuel × thrust × stores = θ

$$\dot{x} = f(x,u,\theta)$$ where θ is partially known

Design choices:

1. Be robust to $\theta \rightarrow u(x)$
2. Let the controller depend on $\theta \rightarrow u(x,\theta)$
3. Be adaptive to $\theta \rightarrow u(x,\hat{\theta})$

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External stores

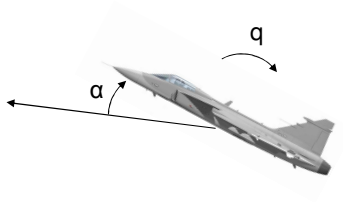
- External stores act **destabilizing**
  1. **Center of gravity** is pushed back
  2. **Aerodynamic** effects

Control solution

- Dynamics:

$$\dot{\quad} = -\frac{(\quad)}{}$$

$$\dot{\quad} = \frac{(\quad)+\quad(\quad)+\quad(\quad)}{}$$



- Solution:
  1. Solve $(\quad)=\quad(\quad)$ for Δu
  2. Add Δu to the nominal control law

Dynamic inversion
(feedback linearization, pole placement)

Control problems

- Constructive method to achieve **care free** aircraft?
- **Clearance** of control laws?
  - How to find **worst case** maneuver + stores combination?
- Framework for aircraft modelling? Want to **merge**
  - **flight** data
  - **wind tunnel** data
  - **CFD** data

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Skeldar V-150

- Unmanned helicopter for surveillance
- Under development
- Based on APID-55 by CybAero

150 kg

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Levels of control

UAV pilot

1. Break point list
2. High level commands
   - Heading, speed, altitude
   - Adjust position

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Guidance

Path generation

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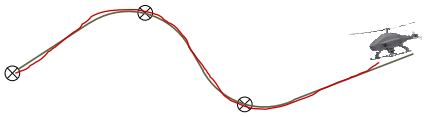
Flight Control System

Control



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Dynamics

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Control problems

- How to **model** helicopter dynamics?
  - Physical modelling
  - System identification
- How to cope with **variations in dynamics** with speed?
  - Gain scheduling
  - Dynamic inversion
  - Robust control
  - Adaptive control

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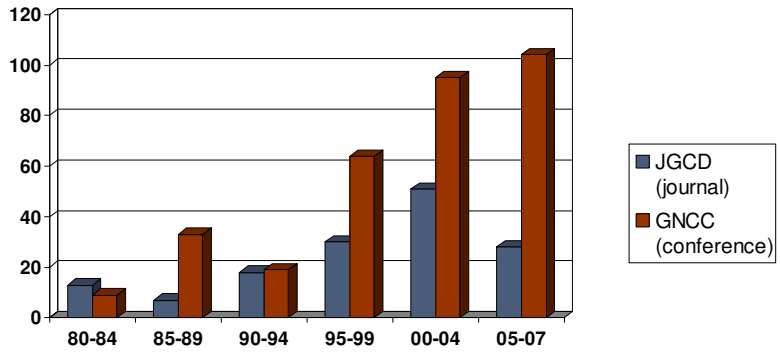
Adaptive flight control

- Publication statistics from AIAA (American Institute of Aeronautics and Astronautics)



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Potential benefits of adaptive flight control

- Improve performance by adapting to unmodelled aerodynamic effects
- Enable first flight with “coarse” model
- Enable flight in larger envelope
- Reconfigure control laws in case of failure
- Give input to model updates

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What is being done?

- Example (Lavretsky et al., 2007):

Make $\dot{x} = Ax + B\Lambda(u+\Theta^T\Phi(x))$

behave as $\dot{\ } =\ +$

- Comparison to pitch control:

Make $\dot{\ } = -\frac{(\ )}{}$

$\dot{\ } = \frac{(\qquad)+\qquad(\ )}{}$

behave as $=\ (\ )$

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Questions

- Could adaptive control be used to **augment** ...

1. Gripen's FCS to cope with uncertainties due to external stores?
2. Skeldar's FCS to cope with variations in dynamics due to speed?

- How to handle **clearance** of adaptive control law?

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