Guidance and Control of re-entry vehicles
ONERA/DCSD - SUPAERO - CNES

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The studies conducted at ONERA and at SUPAERO for the control of re-entry vehicles were divided in three main fields :

- open loop guidance or trajectory optimization (ONERA) ;
- closed loop guidance (ONERA) ;
- attitude control (ONERA, SUPAERO and CNES).

The methods of these three fields were applied to the following vehicles :

- CNES/ESA HERMES project ;
- CNES re-entry capsule project ;
- JAXA HSFD II flight demonstrator ;
- ONERA CENTOR transfer vehicle with aerobreaking ;
- CNES/DLA Reusable Launch Vehicle (RLV).

Some experiences in the development of control design methods and their applications to the control of vehicle during re-entry flying phase can be summarized in the following chronological way:

- the Hermes project leads to extensive exploration of the re-entry physics and of investigation of several control methods :
  - for trajectory optimization : generalized gradient for optimization with many constraints, singular perturbations ;
  - for closed loop guidance : US Shuttle law, near optimal rendez-vous law [Jou91], (fuzzy logic control [Jou97] later) ;
  - for attitude control : LQG synthesis and dynamic inversion [Jou92].

  The Hermes project was characterized by numerous versions of the vehicle and the development of both attitude and guidance laws took into account the dealing of those evolutions.
- the HSFD II project was a cooperation between JAXA and CNES for a flight demonstrator of a vehicle for the transsonic part of the re-entry trajectory. The ONERA study [JFVD07] leads to the definition of an attitude control law using a polytopic method robust on all the HSFD II flight domain and to the extension of the hypersonic US Shuttle guidance law to the final part of the trajectory (instead of switching to another law in approach).
- the current internal ONERA CENTOR transfer vehicle project, in its aerobreaking version, involves dynamic inversion for the attitude control and a modified form of US Shuttle guidance law.

- From a pure methodological point of view, analysis and control design methods that can easily be updated when specifications or characteristics are modified could be very useful engineering tools. Indeed, during primary phases of projects, characteristics of systems evolve significantly requiring easy and efficient control design and analysis methods for high level specification satisfaction. In the case of re-entry vehicle, performance specifications often consist in desired pulsation, damping ratios (flying qualities) and degrees-of-freedom (d.o.f) decoupling. To meet such specifications an H_∞ standard problem based on the acceleration sensitivity function is proposed as a basic scheme [FAIC07]. This standard problem can be used to analyze or design control laws taking into account new dynamic elements (actuators dynamics, navigation filter, ...) or additional specifications (roll-off). This scheme is applied on RLV during atmospheric reentry to design control laws and to determine the worst-case along the reentry trajectory (PhD CNES-ONERA-SUPAERO in progress).

References

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