CALLISTO: towards reusability of a rocket stage: current status

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CALLISTO: towards reusability of a rocket stage: current status

Etienne Dumont, Shinji Ishimoto, Michel Illig, Marco Sagliano, Marco Solari, Tobias Ecker, Hauke Martens, Sven Krummen, Jean Desmariaux, Yasuhiro Saito, Moritz Ertl, Josef Klevanski, Bodo Reimann, Svenja Woicke, René Schwarz, David Seelbinder, Markus Markgraf, Johannes Riehmer, Benjamin Braun and Moritz Aicher

DLR, JAXA and CNES

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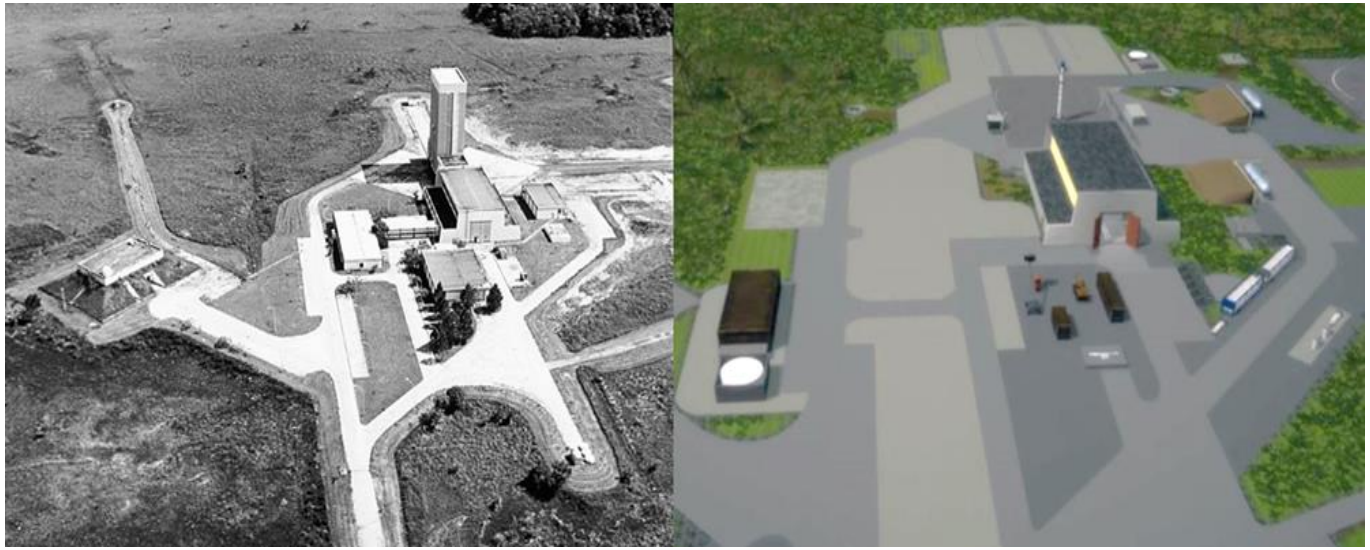
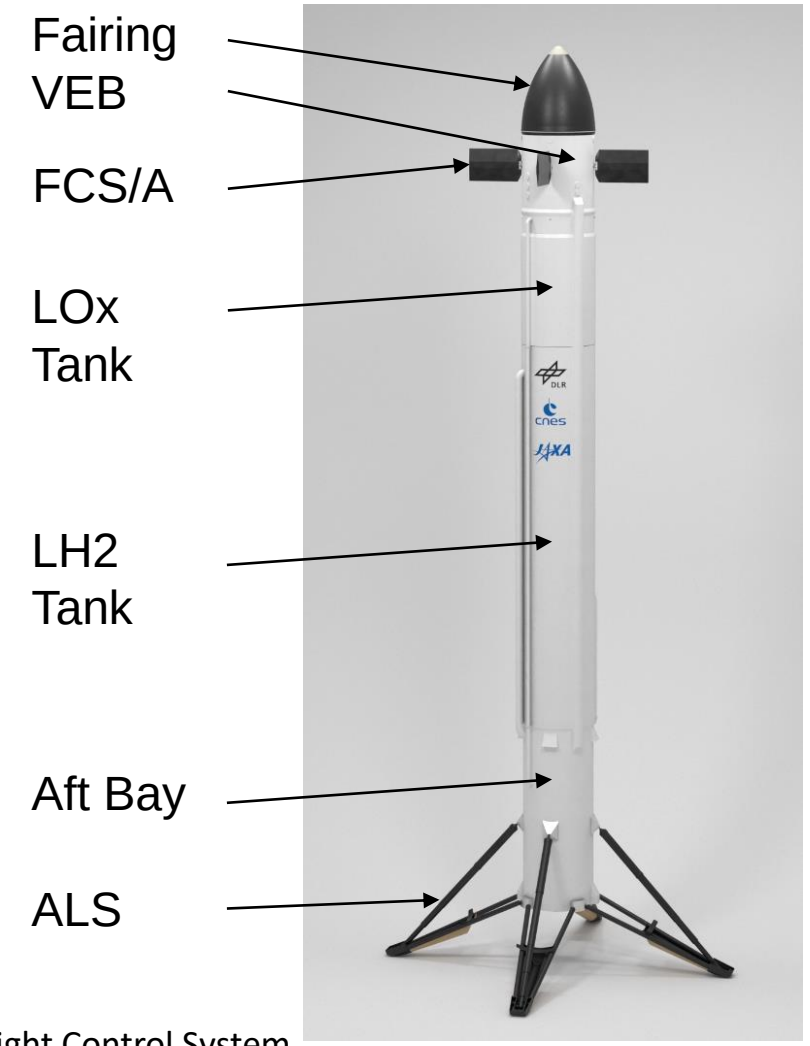
Cooperative Action Leading to Launcher Innovation in Stage Toss - back Operations

CALLISTO is a system made of a vehicle and a ground infrastructure

- The vehicle: 13.5 m high, 1.1 m diameter, less than 4 tons at lift-off
- The ground infrastructure CSG, former Diamant launch pad



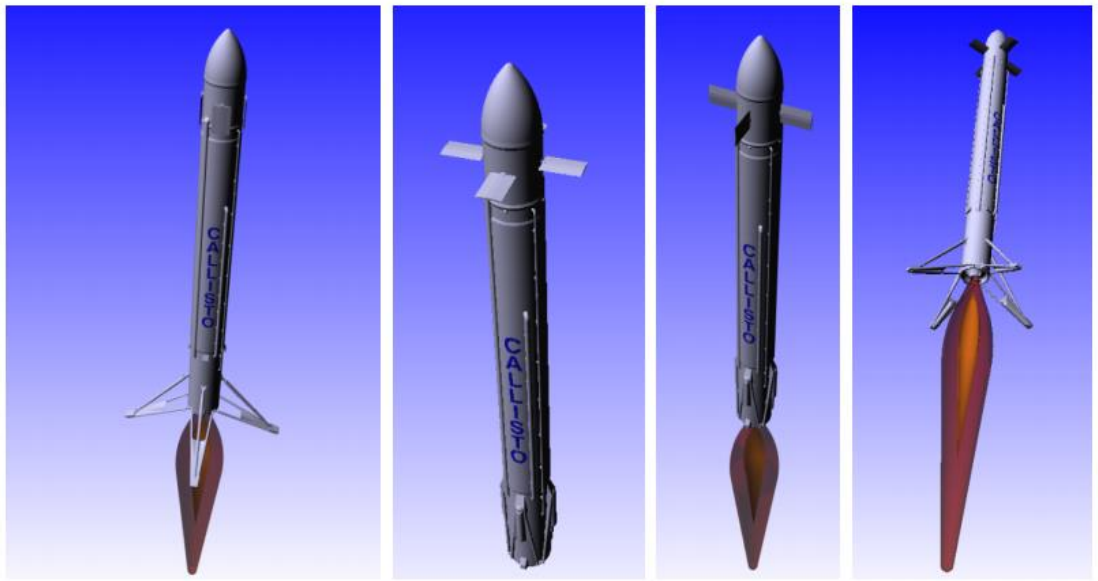


ALS: Approach and Landing System
CSG: Guiana Space Port, Kourou

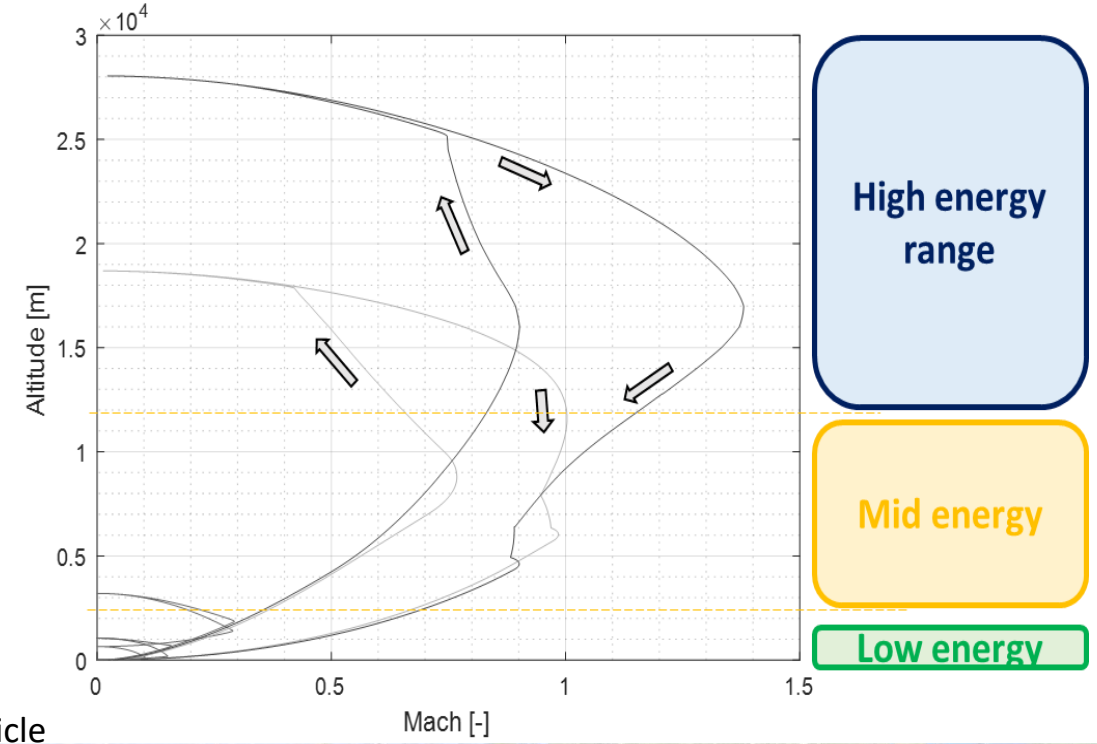
FCS/A Aerodynamic Flight Control System
VEB: Vehicle Equipment Bay

Operation philosophy: towards reusability

- CALLISTO is an experimental vehicle designed to reach flight conditions relevant for future RLV stages.
  - It is characterised for instance by numerous flight configurations
  - Several newly developped technologies that will be tested for the first time under real conditions
    - ➢ stepwise test strategy to reduce risks (maximum 10 flights)



(a) FUO (b) FFN→UFN (c) UFO (d) FUO→UUO



RLV: Reusable launch vehicle

Demo flight

Time	Event	FCS/A	ALS	Engine
0	MEIG#1	F	F	OFF -> ON
120	MECO#1	F	F	ON -> OFF
140	FCS/A unfolding	F -> U	F	OFF
	Reentry	U	F	OFF
200	MEIG#2	U	F	OFF -> ON
230	ALS unfolding	U	F ->U	ON
240	Touchdown	U	U	ON -> OFF

Full video: https://tinyurl.com/2xdyedwy

MEIG: Main Engine Ignition
MECO: Main Engine Cut-Off
F: Folded
U: Unfolded

Demo flight

Time	Event	FCS/A	ALS	Engine
0	MEIG#1	F	F	OFF -> ON
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Operation philosophy: towards reusability

- Maintenance and Repair Operations (MRO) planning
  - Up to 10 flights to be performed in 6 months
  - Product MRO is to be limited -> impact on design
  - Detailed planning of operation is needed
  - AIT operations are intended to be used as rehearsal as much as possible, especially predictive maintenance

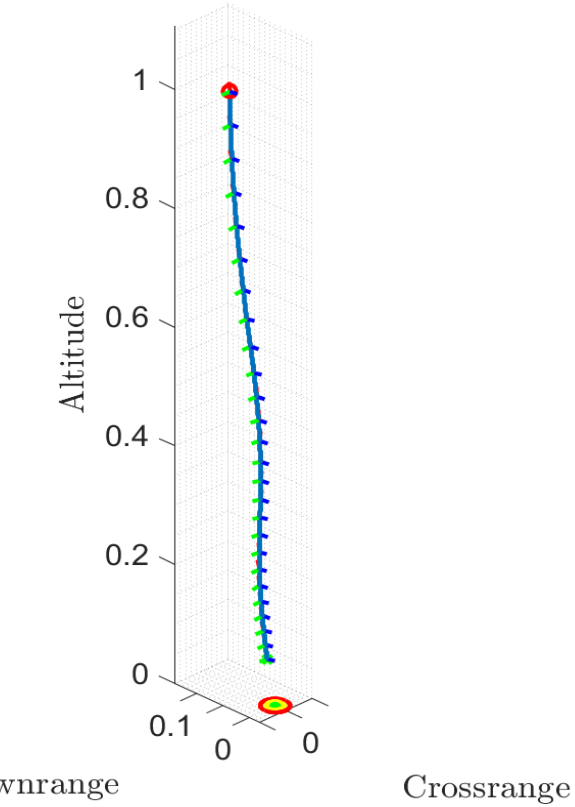
- Flightworthiness
  - Clarify process on how to ensure that a product is able to fly again or not
    - Possible limitations of use or constraints on mission
    - Need for corrective maintenance?

AIT: Assembly Integration and Tests

GNC: current status

- Two G&C software in development based on different methodologies

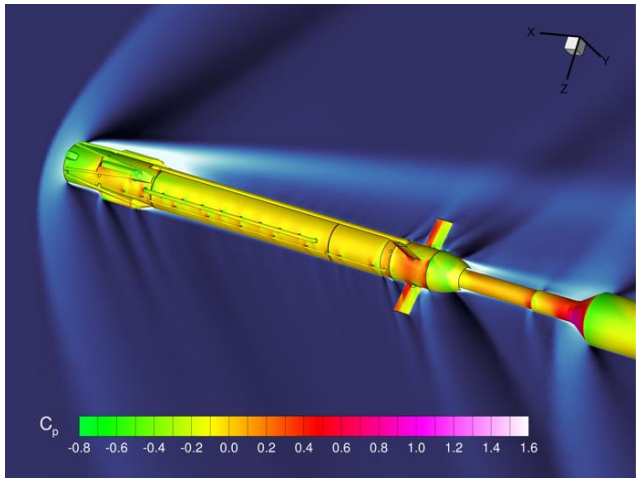
- Work performed in the course of the phase B, to ensure that:
  - the guidance and control methods will be robust while still preserving the performance
  - the navigation system will be reliable and accurate
    - Switch from radaraltimeter to RTK
  - the uncertainties linked with aerodynamic aspects are kept as low as possible
    - Much more than 10000 CFD computations performed
    - 4 Wind tunnel test campaigns
  - the landing and landing leg deployment sequence are well understood and simulated
    - Over 10000 landing simulations performed
    - Deployment and landing test on test bench (see 2022-g-14 – following presentation)

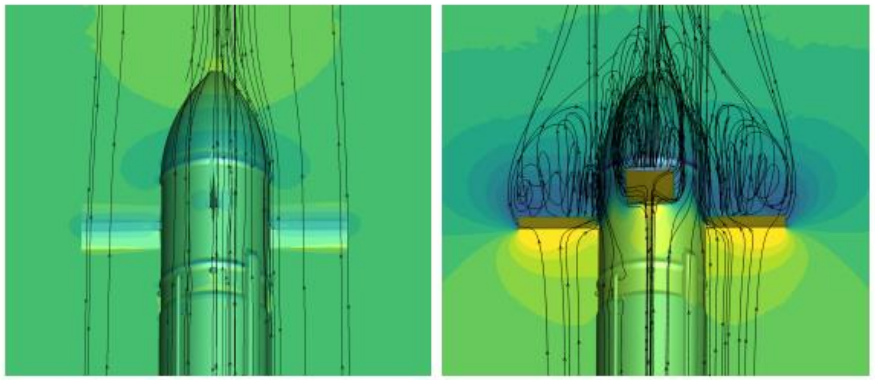


Example of aerodynamic descent trajectory obtained with pseudospectral sequential convex optimization

Aerodynamics: current status

- Impact of aerodynamic characteristics on global performance of CALLISTO is very important
- Impact of uncertainites is also very important: analysis of different turbulence model and different surface roughness
- Aeroshape: optimising a design impacted by several subsystems
- Very large flight domain and consideration of transient configuration: deployment, throttling and TVC



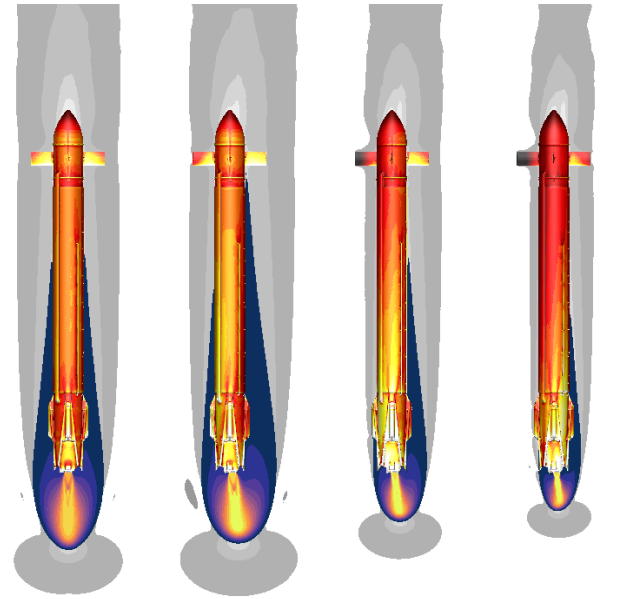


(a) AoF = 0 deg

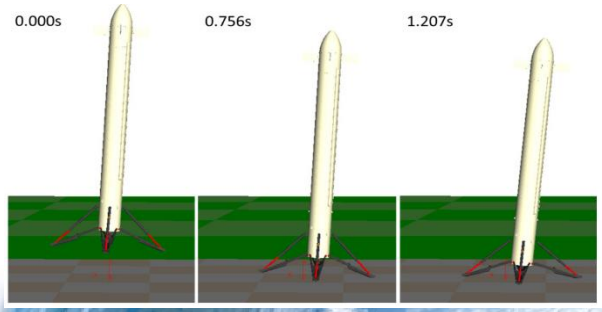
(b) AoF = 90 deg

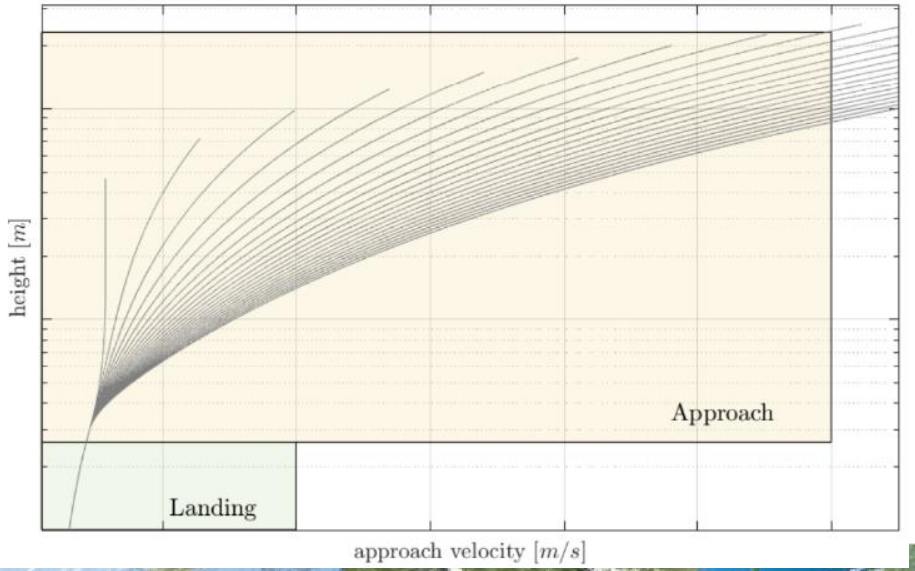
Approach and landing: current status

- Systematic approach developped to cover the full approach flight domain
- Analysis and simulation of the deployment: pneumatically commanded of the ALS: not too late, not too soon
  - Hardware tests
- Analysis and simulation of touch-down and stability after landing (example wind gusts)
- Analysis and simulation of thermal loads during landing boost and after landing



TVC 0° TVC 5° TVC 0° TVC 5°
110% thrust 40% thrust





Conclusion

JAXA, CNES and DLR are developing jointly CALLISTO an experimental vehicle to **pave the way for potential future reusable launch vehicle** in Europe and in Japan.

Very important progress have been achieved on aspects completely new with respect to expendable launch vehicles.

Phase C is about to start.

Manufacturing and tests have already started for EM and some QM, this will accelerate during 2022.

Integration in Japan and tests in Japan and Kourou will follow in the course of 2024 and 2025.

どうもありがとうございます