Update for DLR RLV demonstrator projects: ReFEx and CALLISTO

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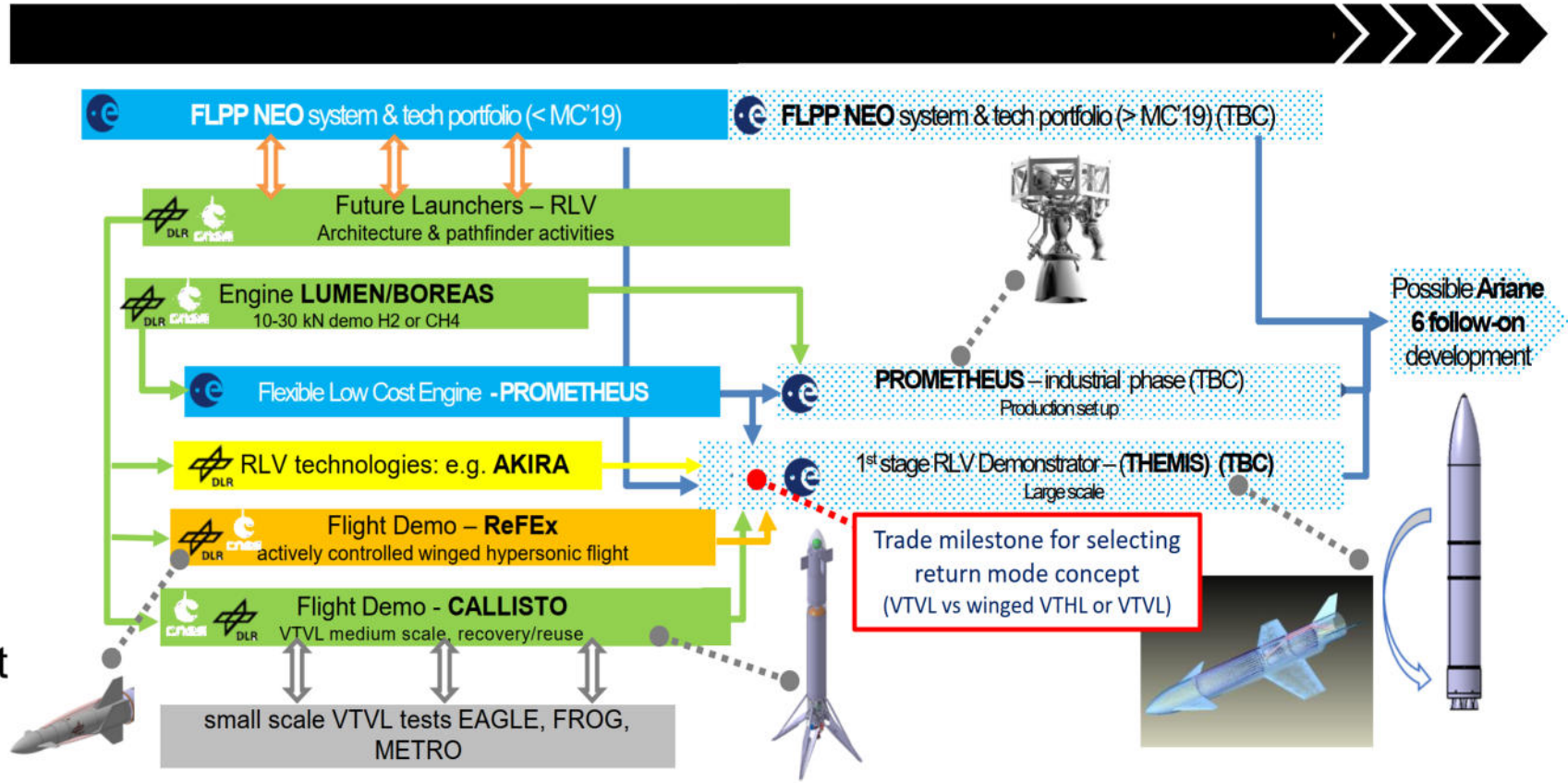
DLR

Introduction & the RLV Roadmap

- RLV key to future space transportation
  - Different approaches
    - Winged (VTHL)
    - Toss-Back (VTVL)
  - DLR follows joint roadmap
  - Both types in development as technology demonstrators
  - Various system studies & ancillary technology to support RLV efforts



Reusable Launch Vehicle Technology Demonstrators

CALLISTO

- Propellant management
- Re-use operational aspects
- Landing & touch-down dynamic
- Reusable cryo-tanks and structures
- Pin point vertical landing

Shared

- Real time multicore processing
- GNC for RLV
- Health monitoring
- Aerodynamic design
- Controlled trans-sonic flight

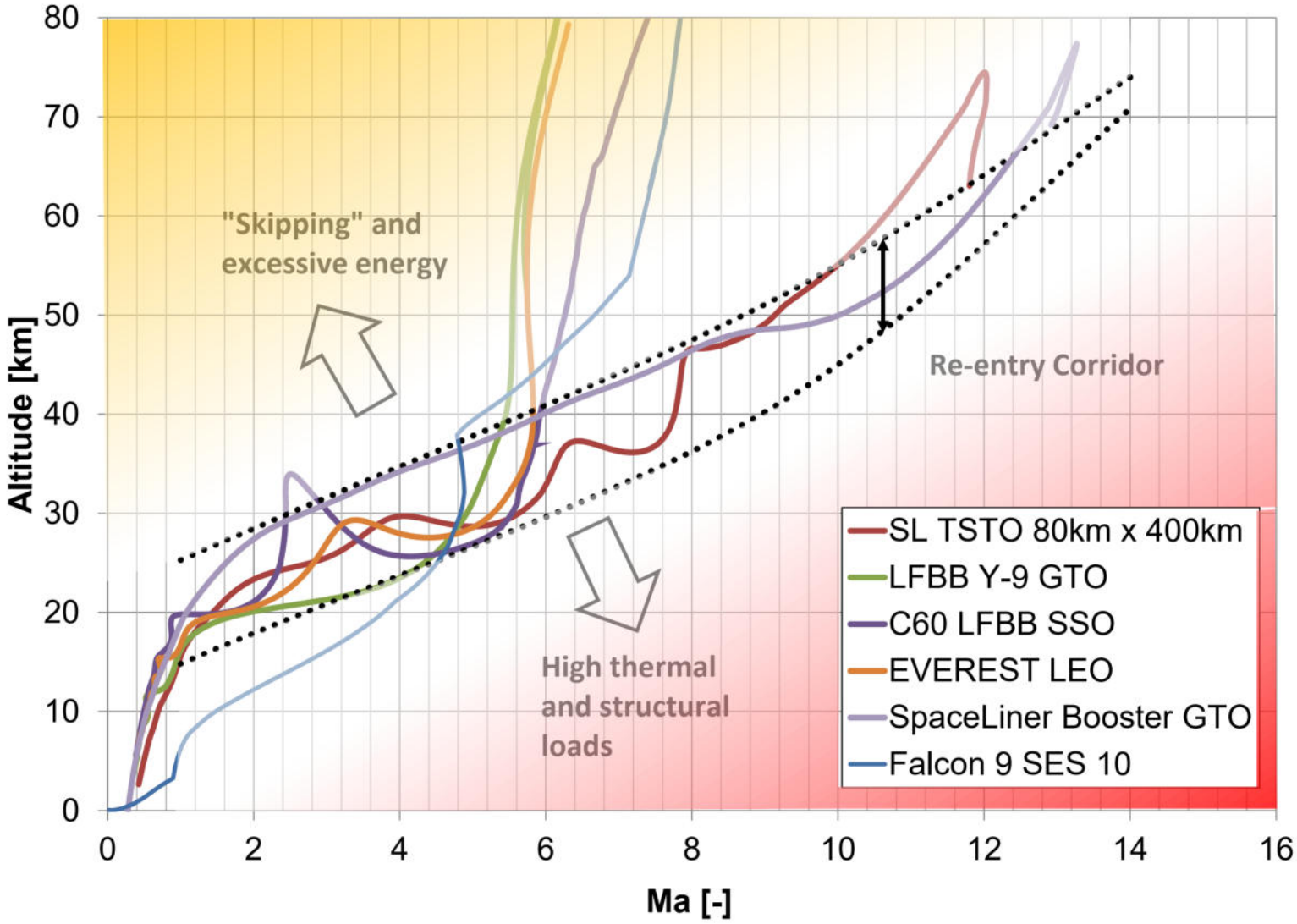
ReFEx

- Controlled hypersonic flight
- Advanced aero sensors (FADS)

- Post flight inspection
- High maneuverability initiating aerodynamic RTLS

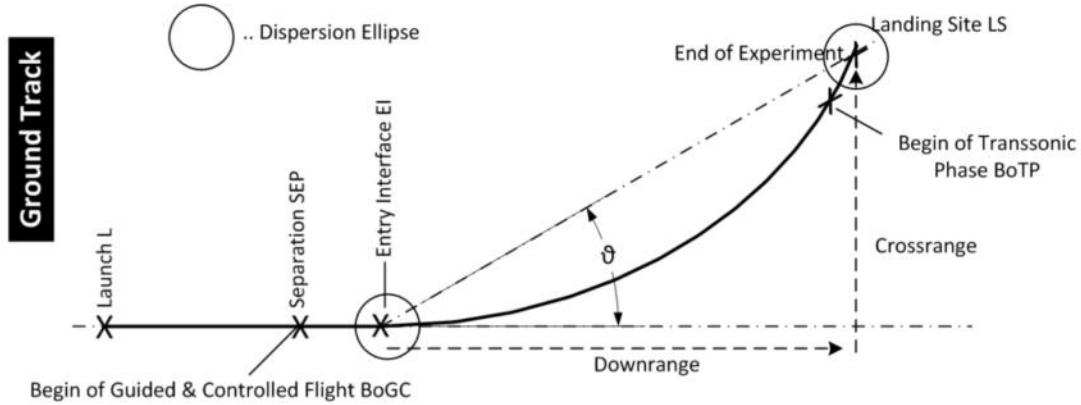
ReFEx

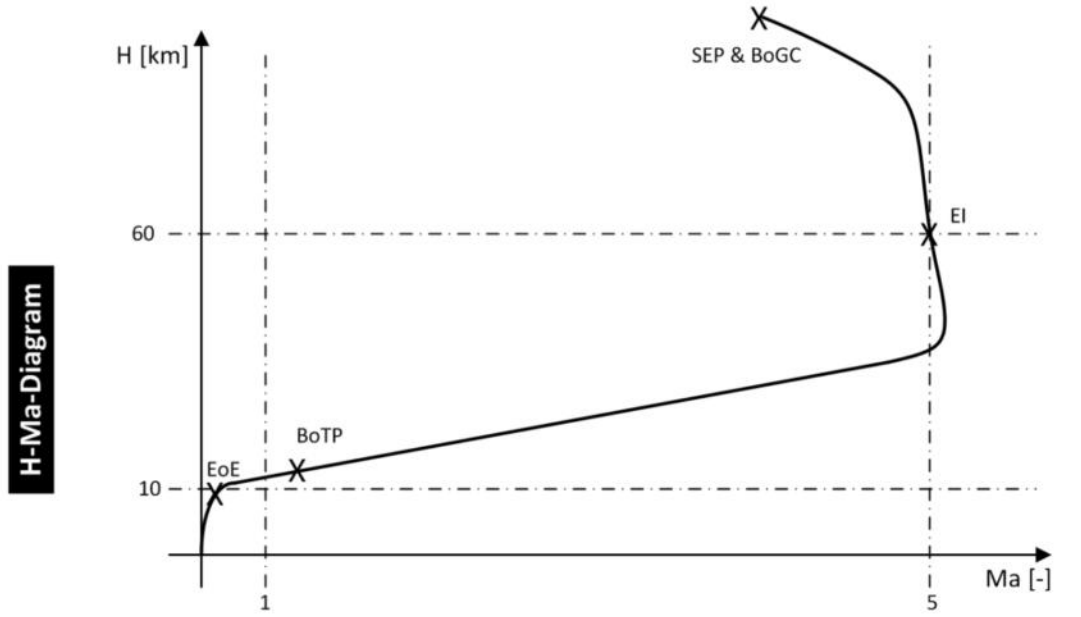
Winged-RLV Corridor – Important for any Winged-RLV



ReFEx – Main Project Goals

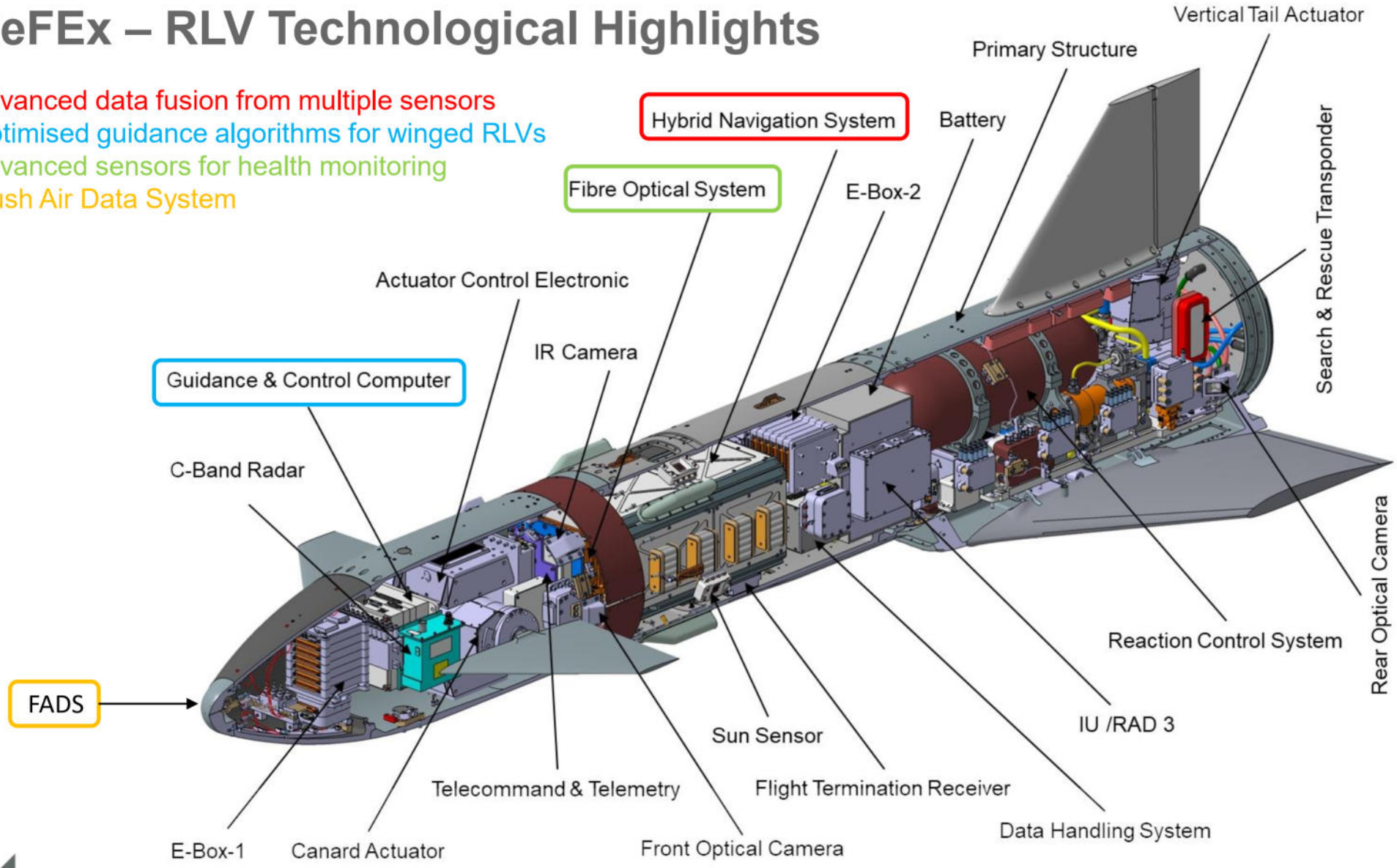
- **ReFEx…**
  - …is a technology demonstrator for a winged reusable first stage
  - …will traverse a large flight envelope of hyper- / super- / trans- and subsonic flow
  - …will perform altitude and velocity management using a multi AoA & bank angle flight profile
  - …will demonstrate maneuverability by flying at least a 30° heading change
  - …will use GNC capable of autonomous on-board trajectory generation and optimization
  - …will demonstrate the seamless transition from extra- to intra-atmospheric flight
  - …will use advanced sensors (FADS & FOS) for flight data acquisition
  - …will increase DLRs know-how of winged RLVs
  - **WILL LAUNCH IN 2023**



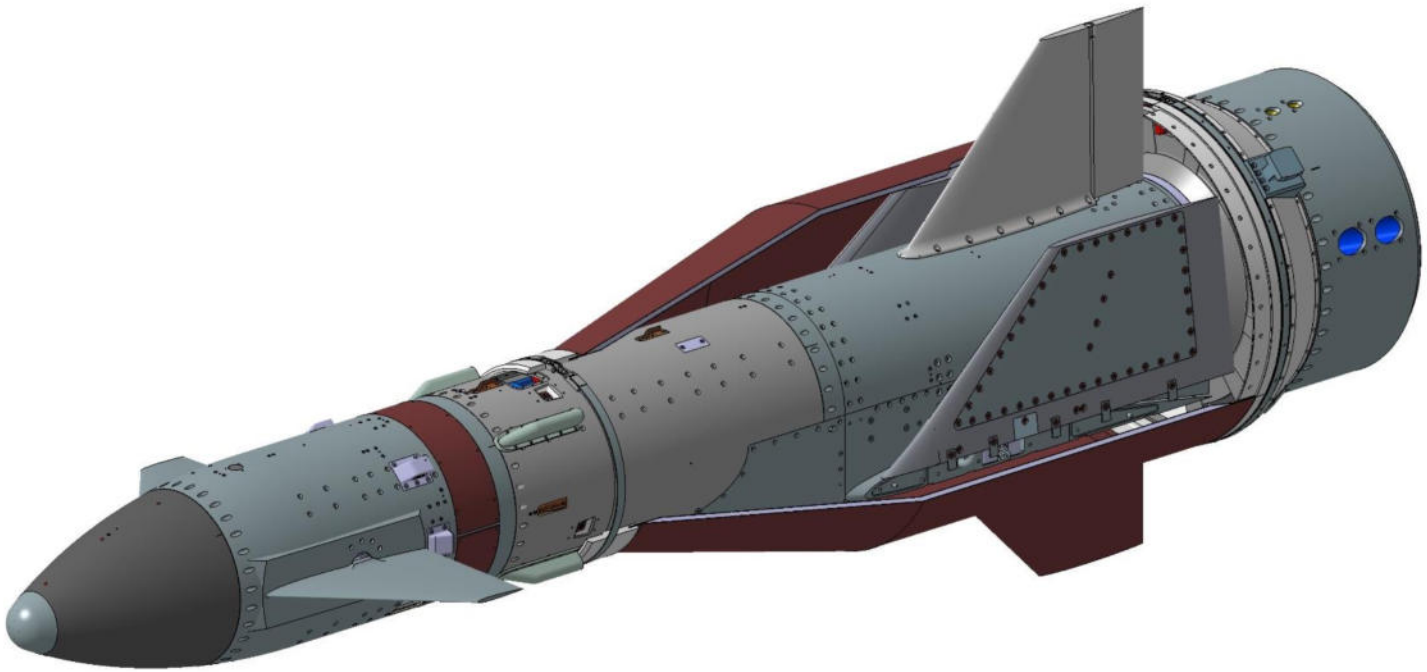


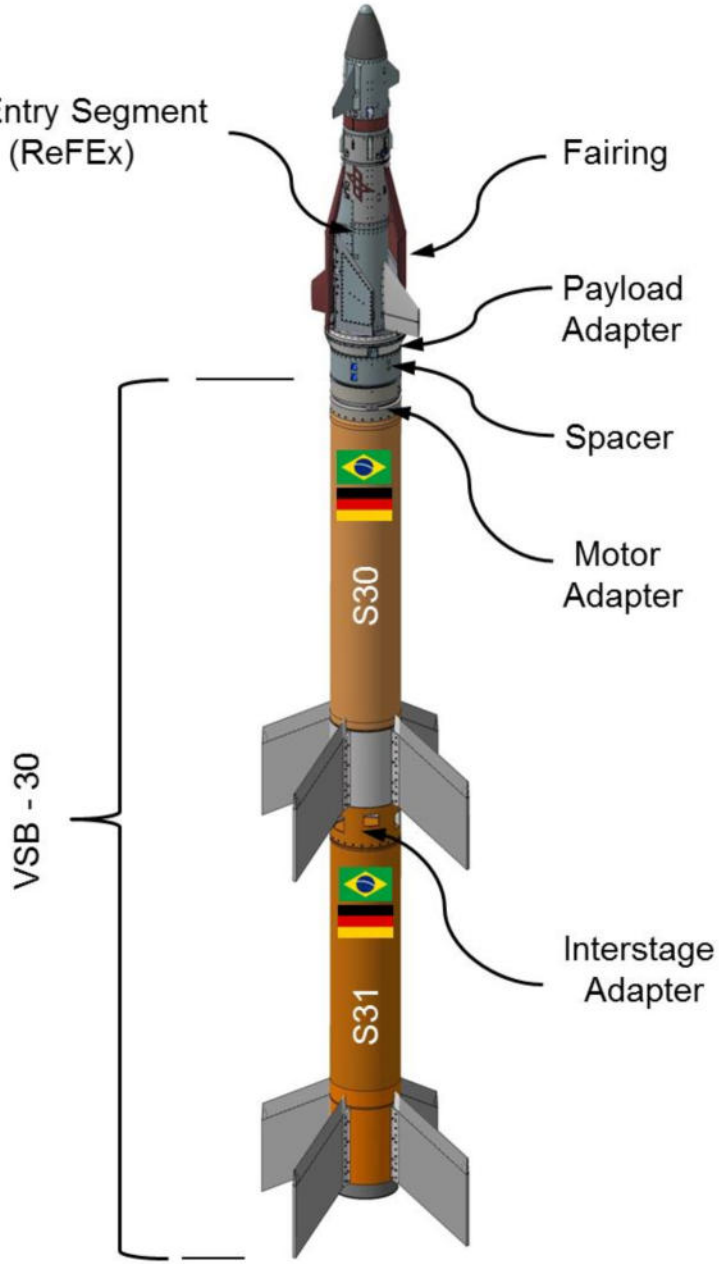
ReFEx – RLV Technological Highlights

Advanced data fusion from multiple sensors
Optimised guidance algorithms for winged RLVs
Advanced sensors for health monitoring
Flush Air Data System

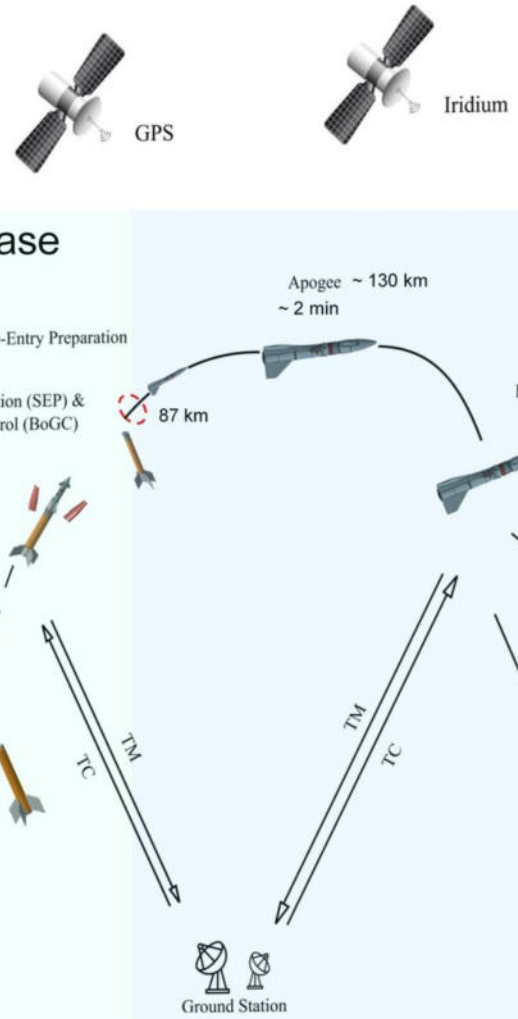


ReFEx – Launch & Re-Entry Konfiguration





ReFEx – Mission Events



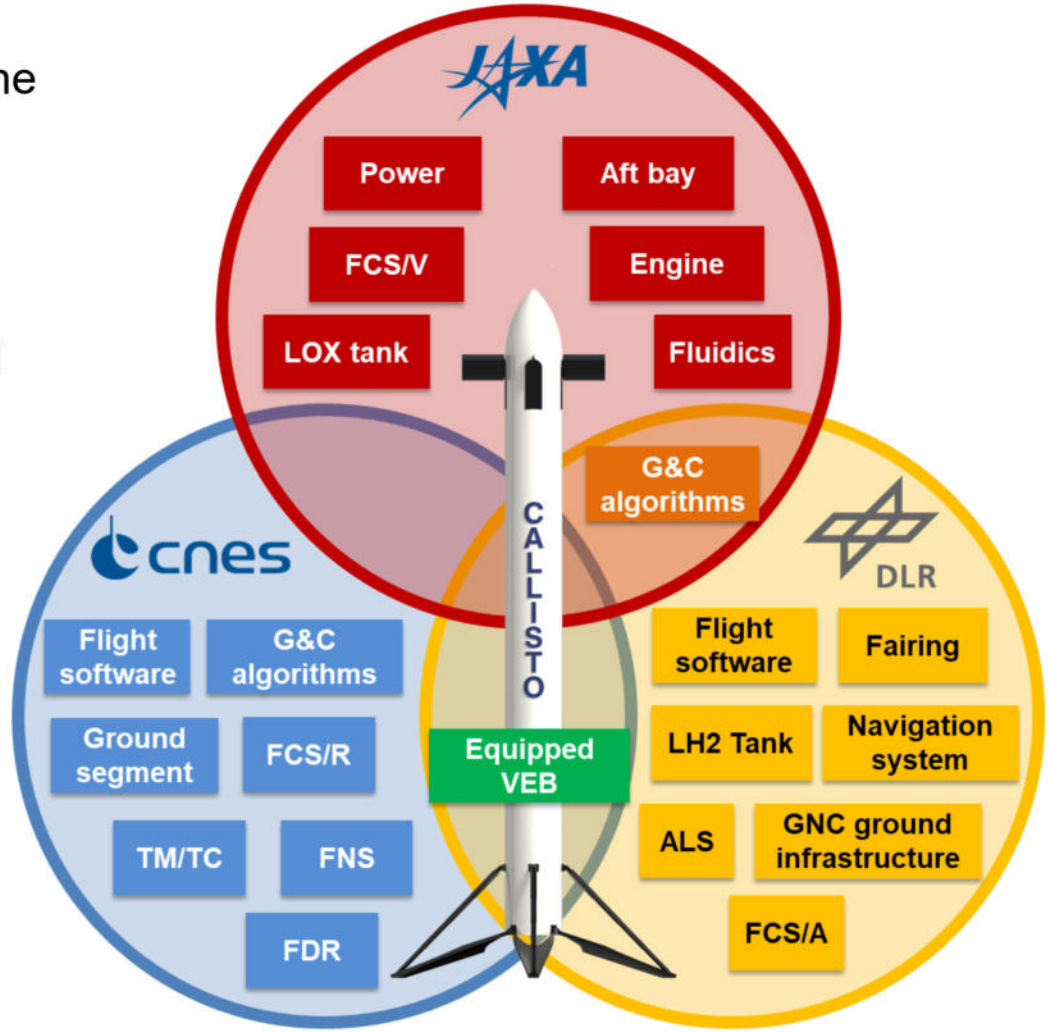
ReFEx – Conclusion / Outlook

- ReFEx has a long development history with many design challenges addressed
  - Already valuable lessons learned from the current design and its evolution
- ReFEx reached PDR Status May 2019
  - A delta PDR with some remaining items to be closed is scheduled for Q3 2020
- ReFEx is currently progressing toward System CDR in Q2 2021
- Flight is scheduled for 2023
  - Valuable flight data and experience toward winged RLV stages
- Will help informed decisions about future European reusable launcher

CALLISTO

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

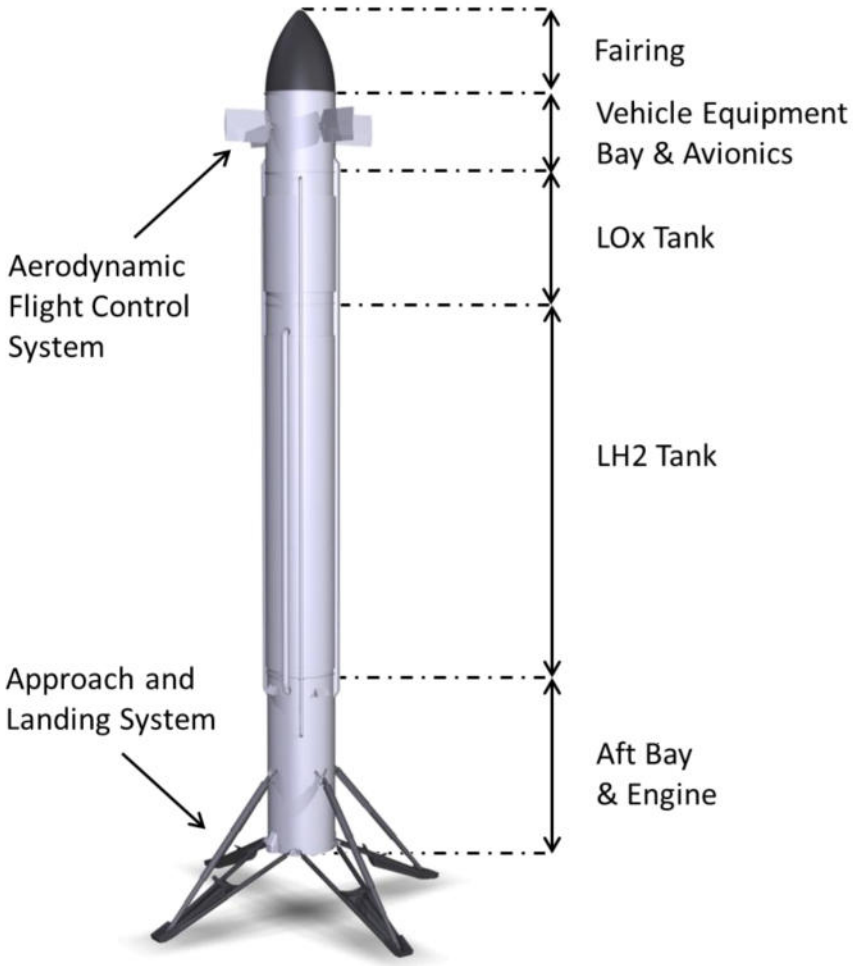
- **DLR, CNES and JAXA cooperation** initiated in June 2017. Currently finishing phase B.
- **Main goals**
  - Collect **technical and economic** data relevant to an operational RLV
  - **Technology demonstrator** for a vertical take-off, vertical landing rocket first stage e.g.
    - Landing system
    - GNC
    - Propellant management
    - Reusability
    - Accurate landing with high thrust to weight ratio
  - **Up to 10 flights** with the same vehicle
  - Flight envelope:
    - Super- / Trans- and Subsonic
  - **Limit refurbishment** effort and time
  - Increase of **RLV know-how** and refine analysis tools for RLV design and development
  - **Test campaign in Kourou planned 2022**



ALS: Approach & landing system
FCS/A: Aerodynamic control surfaces
FCS/R: Reaction control system
FCS/V: Thurst vector control
FDR: Flight data recorder
FNS: Flight neutralization system
G&C: Guidance and control
TM/TC: Telemesure and telecommand
VEB: Vehicle Equipment Bay

Further system aspects shared between CNES, DLR and JAXA

CALLISTO – a technology demonstrator for future RLV



Rely on European and Japanese heritage and know-how

Integral tanks

Pneumatically deployable **landing system**

Three flight control systems

- 40 kN class **LOx/LH2 expander bleed engine**
  - Re-ignitable
  - Continuously throttleable (down to less than 40 % of the max. thrust)
  - TVC
- **RCS:** H2O2 Reaction Control System
- Four deployable **aerodynamic control surfaces**

GNC relying on hybrid navigation (DGNSS, radar altimeter, …) **convex optimisation, …**

GLO mass about 3500 kg

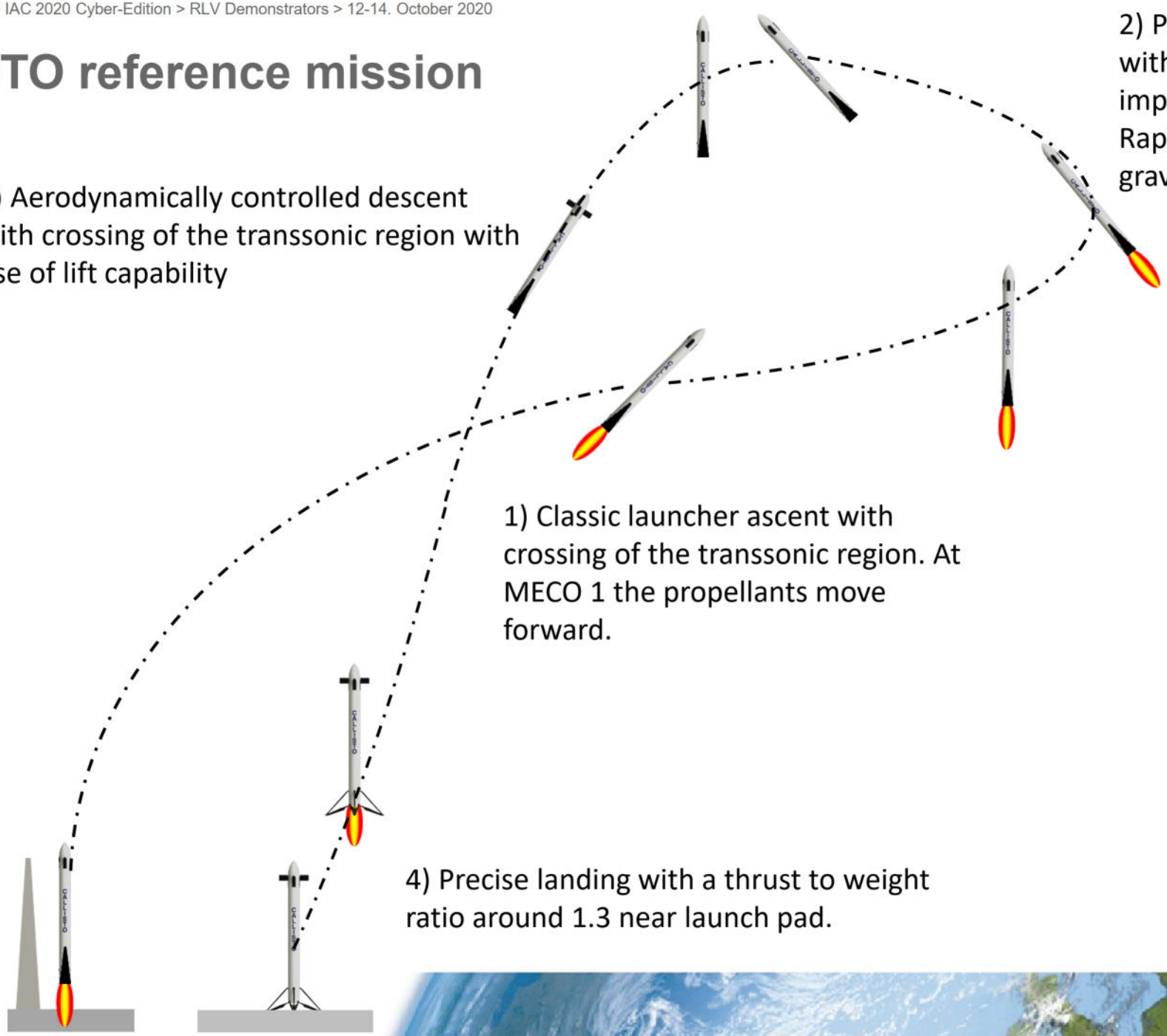
Diameter: 1.1 m

Length: 14m

CALLISTO reference mission

2) Powered tilt-over and boost back with change of the instantaneous impact point. (h > 25 km)
Rapid change of attitude under low gravitational acceleration

3) Aerodynamically controlled descent with crossing of the transsonic region with use of lift capability



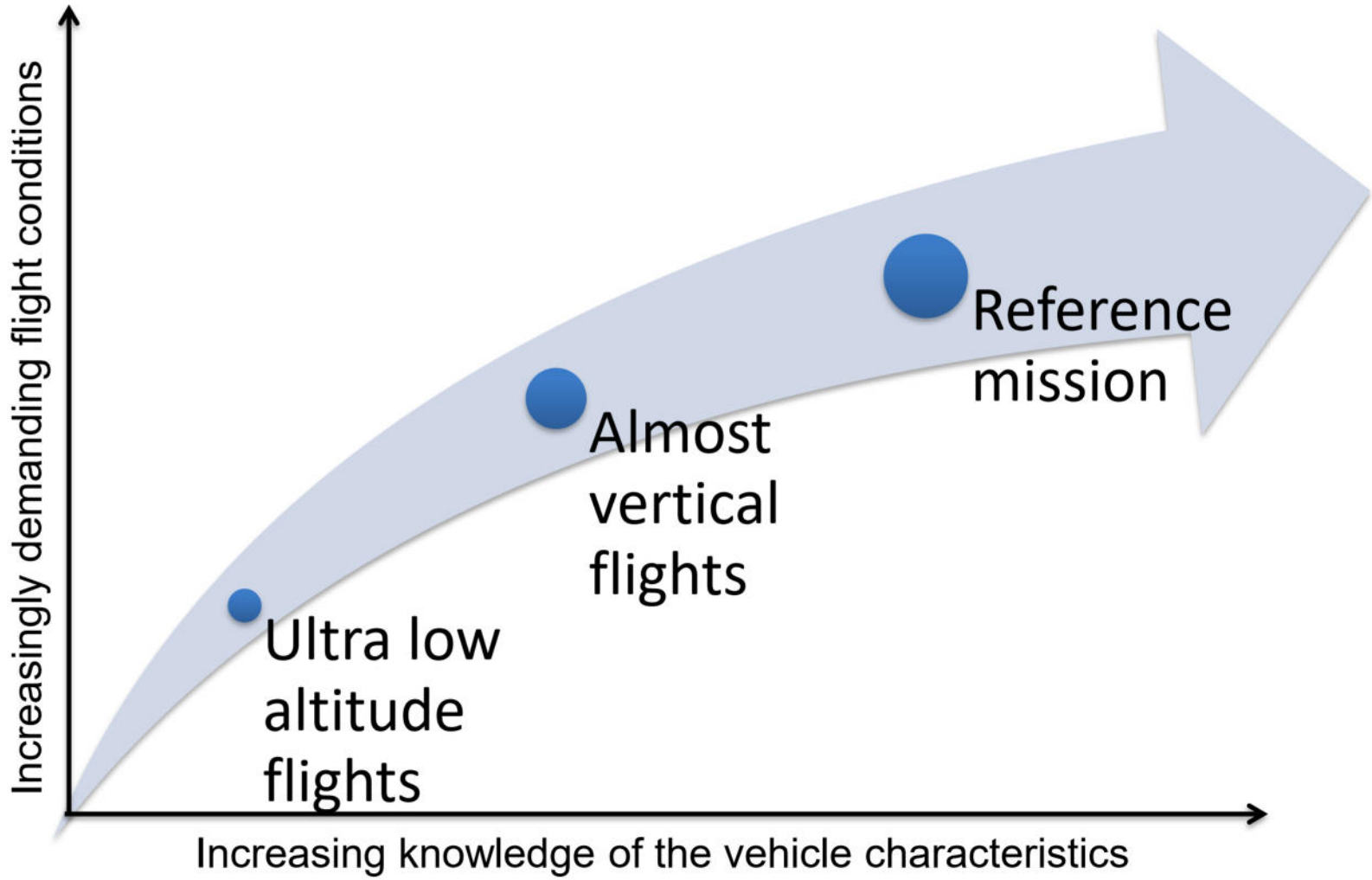
1) Classic launcher ascent with crossing of the transsonic region. At MECO 1 the propellants move forward.

4) Precise landing with a thrust to weight ratio around 1.3 near launch pad.

Not to scale

CALLISTO Incremental Demonstration Logic

- **More than forty manoeuvers and events** of interest identified
- Implementation of limited new features at each flight to **limit risks**
- **Investigation** at technological and operational level **of reutilisation** after each flight
- Up to 10 flights



CALLISTO – Conclusion / Outlook

- **Sharing of tasks** between the three international partners consolidated
- **Launch place** has been selected and flight safety analyses are on-going
- **Numerous engineering tests** on-going/about to start
- **Main engine** test on-going
- **PDR-Product** planned for early summer 2021
- **Integration and hot firing tests** are planned in Japan
- **Combined tests, risk reduction flights and demonstration flights** are planned for 2022 in Kourou
  - Valuable flight data and experience toward VTVL stages and in general reusable vehicle ground operations
- Will help informed decisions about **future European reusable launcher**

RLV Demonstrators – Conclusion

- **DLR is in a unique position:**
  - **Two technology demonstrator projects** with different approaches
  - Allows for **real comparison** of pros & cons for each approach
  - Valuable lessons learned for **future European RLVs** (vehicle, ground segment and operations)
  - **Reduction of development risk** for operational vehicle through testing at smaller scale
  - Valuable dataset to improve the validity and accuracy of **system studies**
  - **Open to join larger RLV initiatives in Europe with expert advice gained from flight experiments**