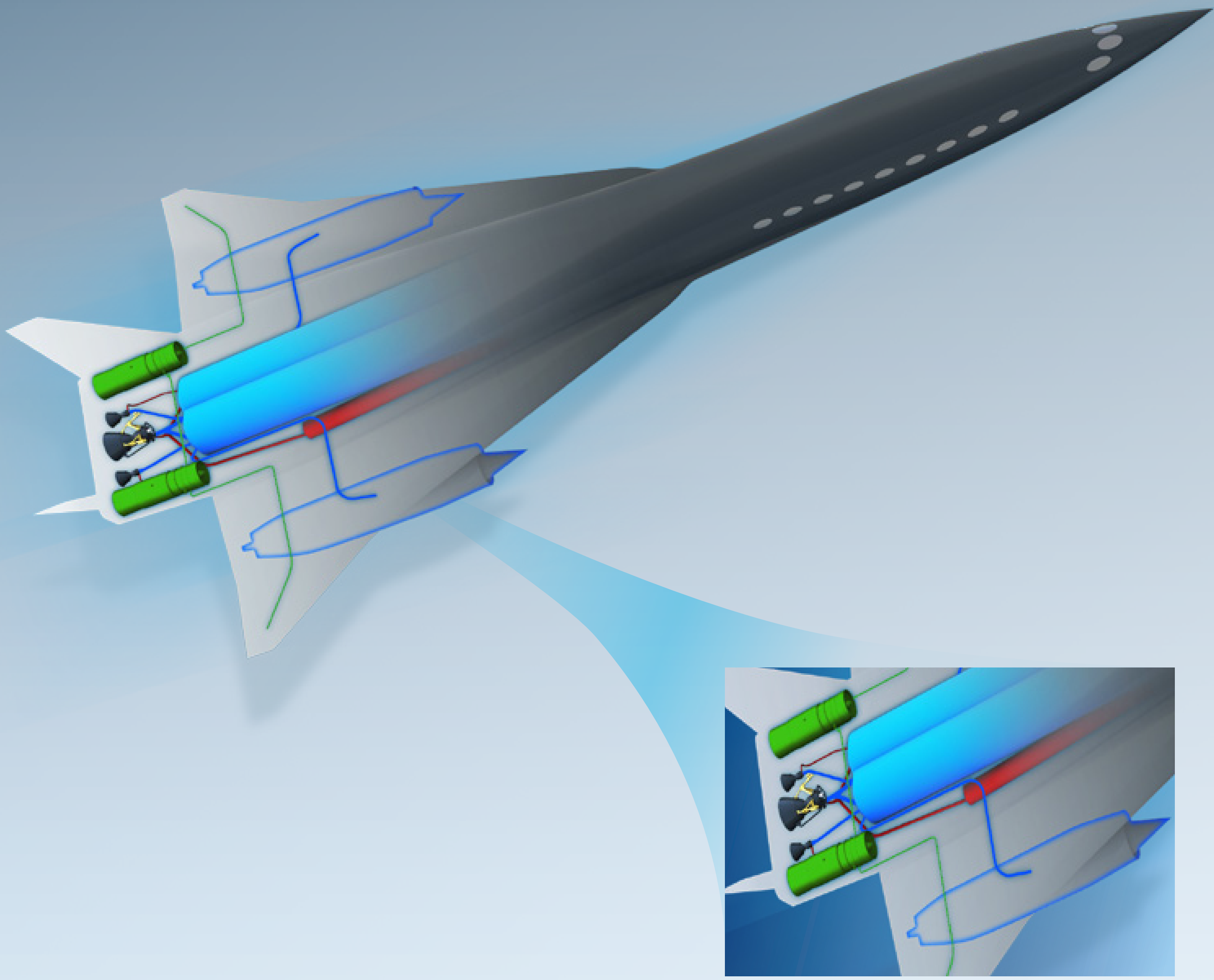
EADS INNOVATION WORKS and ASTRIUM

ZEHST

High-Speed Transport Concept Study



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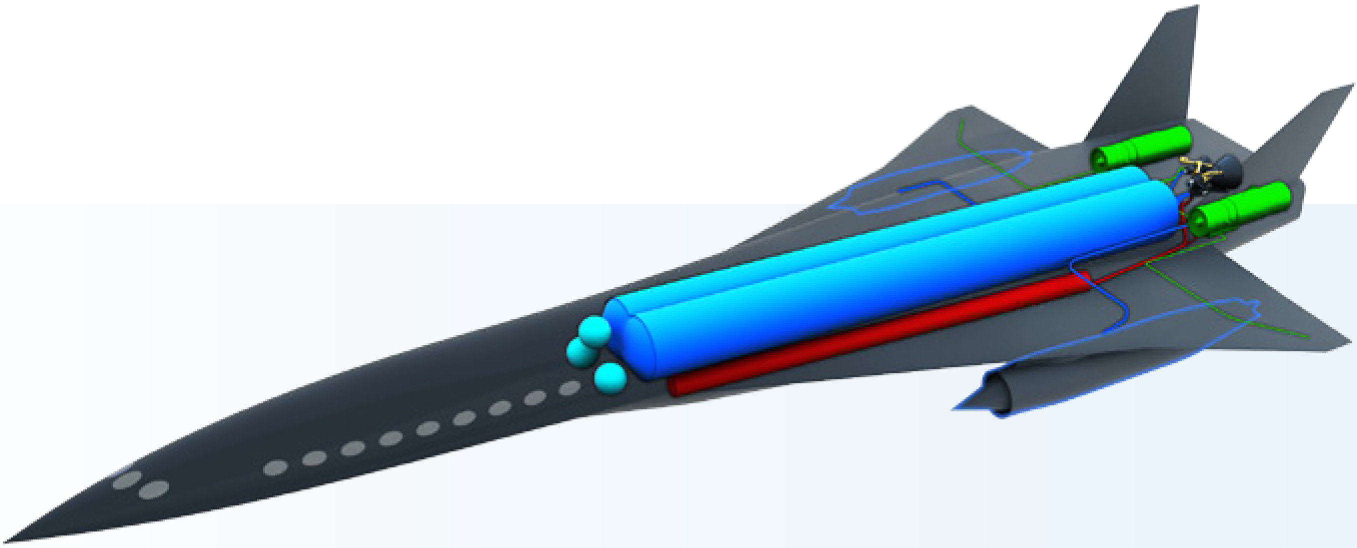

EADS INNOVATION WORKS and ASTRIUM – in partnership with the French ONERA national aerospace research laboratory – have launched a feasibility and systems study **sponsored by the French Agency Direction Générale de l'Aviation Civile (DGAC)** for a future commercial high-speed transport system that could fly long-haul routes – typically Tokyo-Los Angeles or Tokyo-London – in less than 2 hr. 30 min., while having minimal environmental impact and being operated as a standard aircraft.

Called ZEHST, this high-speed transport concept definition **uses know-how from ASTRIUM's sub-orbital Spaceplane**, and is one of the projects incorporated in EADS INNOVATION WORKS' eCO_2avia activities – which also include such efforts as demonstrating the feasibility of biofuels and electric power for aviation use.

Reducing travel time for passengers has been – and will continue to be – a key driver in development of the world's air transportation system. Not only will long-haul airliners of tomorrow have to be fast, they also will need to meet the air transport industry's ambitious environmental goals – including those spelled out in the European Commission's roadmap, "Flightpath 2050 – Europe's Vision for Aviation." This European Commission report sets targets for a reduction of aircraft CO_2 emissions by 75%, along with decreases of NOx emissions by 90% and noise levels by 65% – all compared to 2000 levels.

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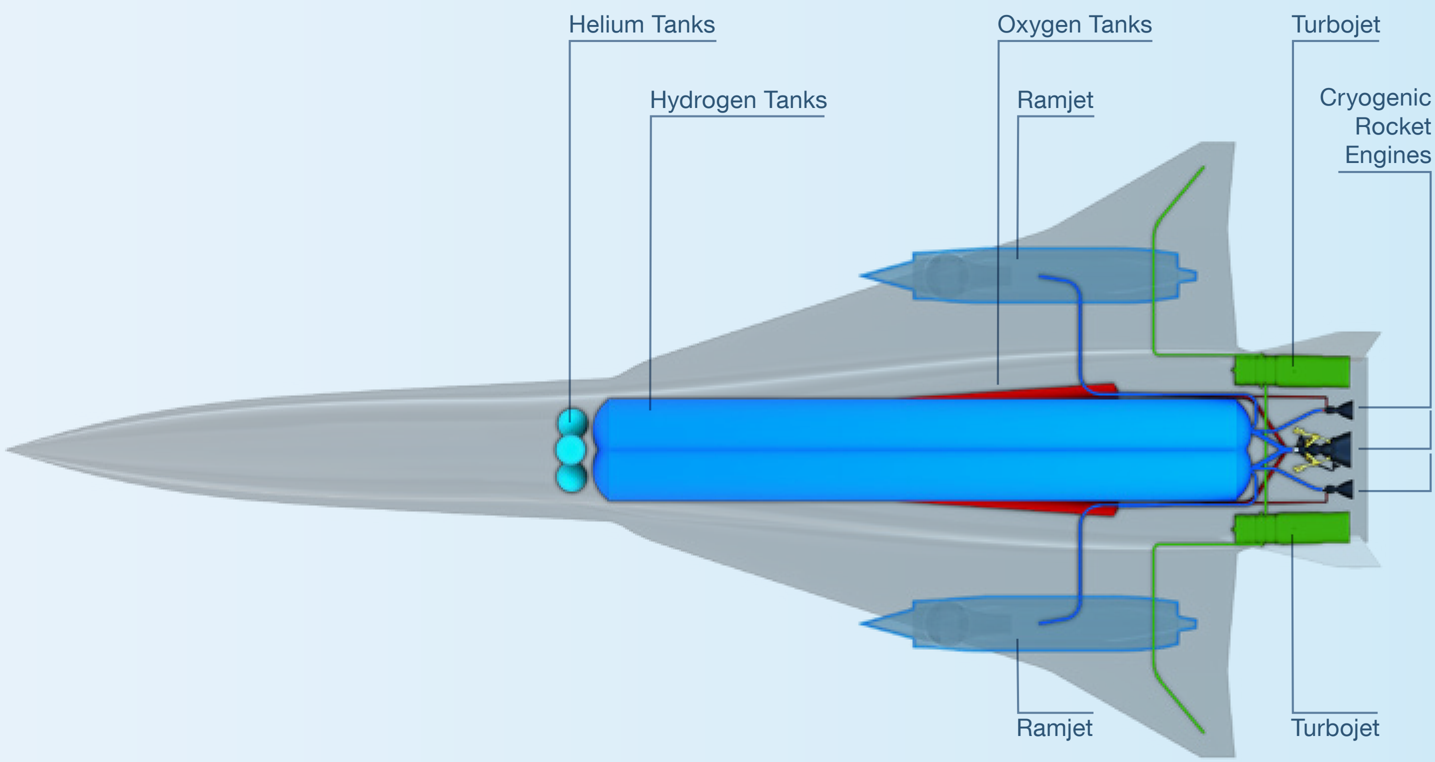
Project Roadmap

ZEHST demonstrators are planned for the end of this decade, followed by development of an operational vehicle. Numerous technological challenges require mastering so that future high-speed commercial transport systems can achieve the required performance and meet tomorrow's environmental constraints. Studies must identify how requirements and objectives can be aligned with technical aspects. In this context, **the following tasks are being performed in the ZEHST project's framework:**

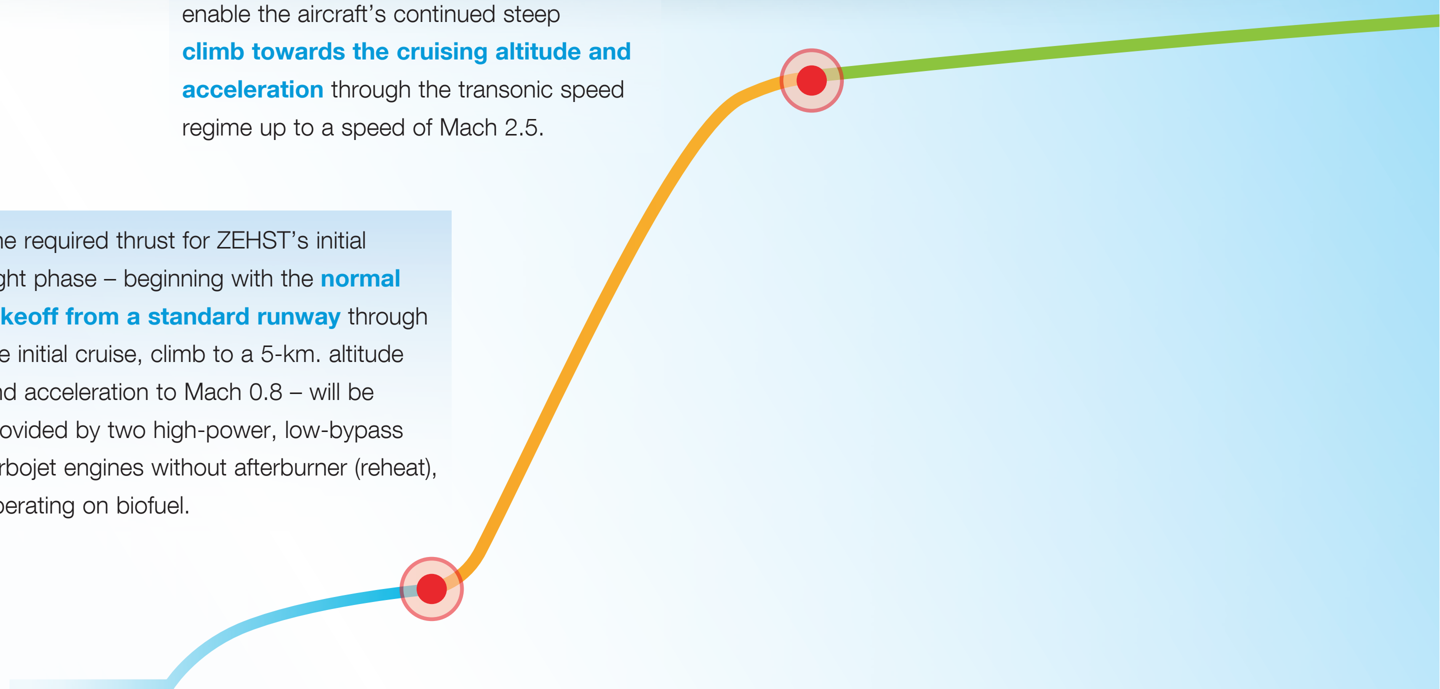
- Establishing an initial set of design requirements and objectives
- Iterative development of reasonable technical solutions
- Rating of new technologies with respect to their applicability, maturity and the associated benefits and risks
- Identifying, evaluating and selecting promising new technologies, and initiating their application-oriented development
- Evaluation of innovative service opportunities offered by this concept

An initial ZEHST propulsion system concept based on liquid hydrogen as the main fuel has been conceived as the first step towards a basic reference solution, which subsequently will be provided to the partners' respective competence centres for in-depth technical feasibility analyses. In addition to the aircraft's initial definition, the ZEHST project also will establish a **technology maturation plan and the preliminary definition of associated test beds**. The next steps in this long-term project then will validate the concept's environmental signature and its propulsion system architecture. **The type of fuel to be used will be selected based on environmental performance, as well as its production and distribution**, while also addressing energy management and the concept's acceptance by future passengers, crew, and the public. Tests and demonstrators will be critical milestones towards completion of this second phase of the roadmap. **The project's third step will deal with product requirements** of a high-speed aircraft capable of flying hypersonic intercontinental missions while still being "green," quiet and operated as a year 2050-standard aircraft.



Ignition and operation of two small liquid hydrogen/liquid oxygen-powered booster rocket engines, followed by the ignition of a larger one (derived from the types used in the Ariane commercial launch vehicle), enable the aircraft's continued steep **climb towards the cruising altitude and acceleration** through the transonic speed regime up to a speed of Mach 2.5.

The required thrust for ZEHST's initial flight phase – beginning with the **normal takeoff from a standard runway** through the initial cruise, climb to a 5-km. altitude and acceleration to Mach 0.8 – will be provided by two high-power, low-bypass turbojet engines without afterburner (reheat), operating on biofuel.



Take-off from standard runway (turbofans)

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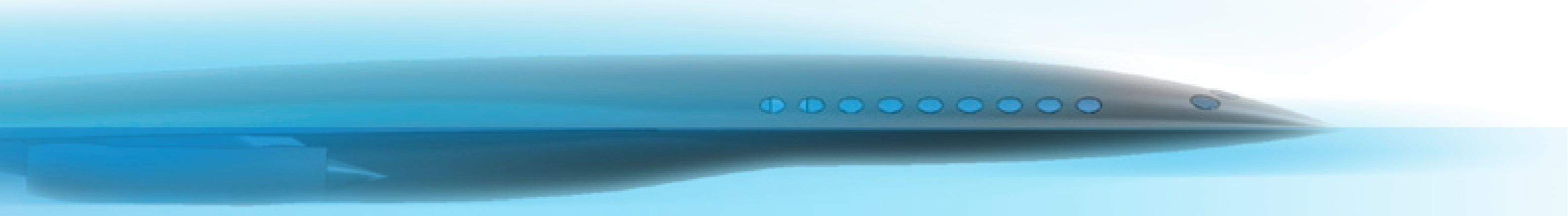
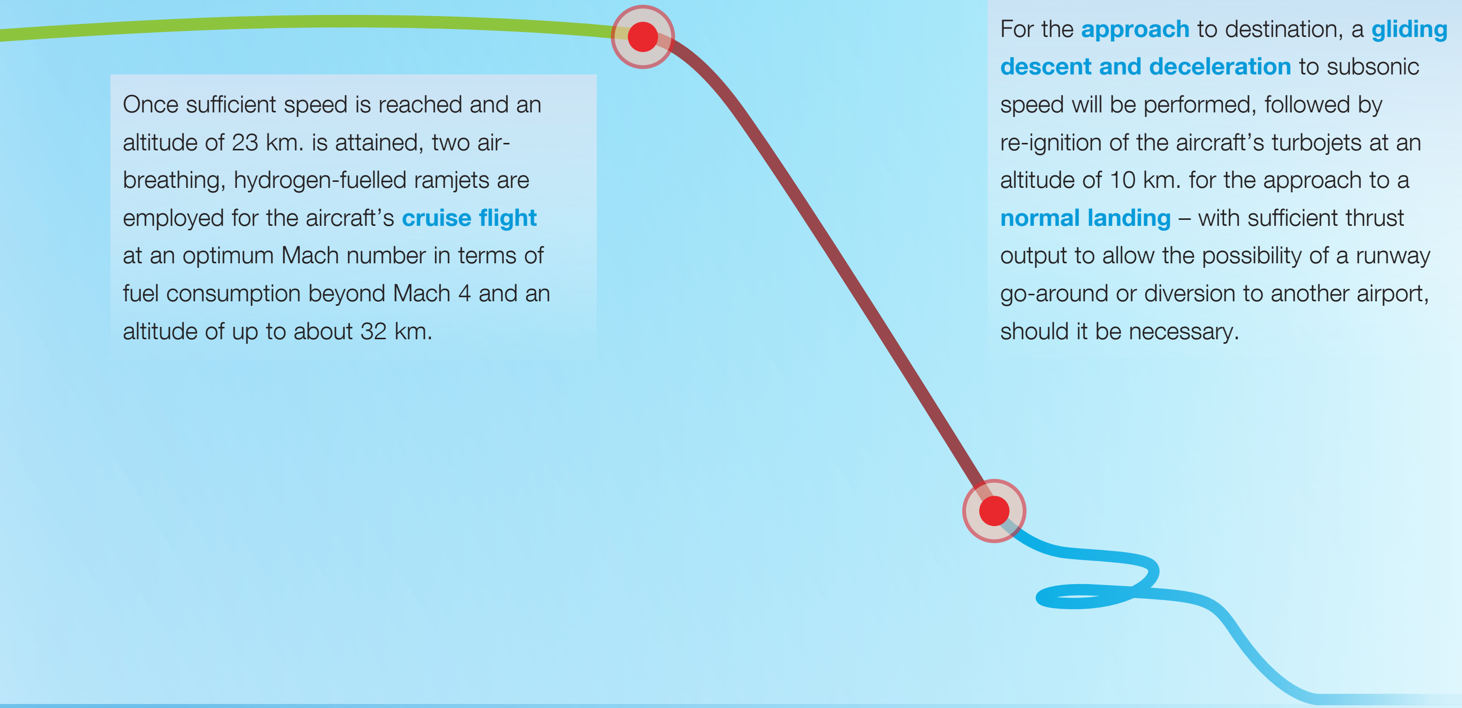
The initial concept represents a propulsion system architecture which is driven by flight safety considerations and by the requirements **to minimize exhaust gas and noise emissions, in particular the mitigation of the sonic boom.** Three types of engines are operated in sequence for the various phases of a long-range flight at hypersonic cruise speed. Mastering the flight profile's ascent and descent phases will benefit from the know-how derived from research conducted for ASTRIUM's Spaceplane over the past five years.

An overarching design criteria of the ZEHST concept is that **passengers should have a "normal," comfortable in-flight experience** without requiring any special equipment or training. For a short period of time during the steep rocket engine-powered climb and acceleration, ZEHST passengers would feel mild acceleration forces (not exceeding 1.2g).



Once sufficient speed is reached and an altitude of 23 km. is attained, two air-breathing, hydrogen-fuelled ramjets are employed for the aircraft's **cruise flight** at an optimum Mach number in terms of fuel consumption beyond Mach 4 and an altitude of up to about 32 km.

For the **approach** to destination, a **gliding descent and deceleration** to subsonic speed will be performed, followed by re-ignition of the aircraft's turbojets at an altitude of 10 km. for the approach to a **normal landing** – with sufficient thrust output to allow the possibility of a runway go-around or diversion to another airport, should it be necessary.



Loiter, approach and landing on standard runway

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Research Topics

The ZEHST concept will focus research in various aspects of future high-speed air transportation systems, addressing such topics as:

- **Evaluating hydrogen as a fuel**, including whether it is a viable and more environmentally-acceptable alternative to hydrocarbon biofuels
- **Examining water vapour and NOx** emissions for the aircraft's ramjet mode during various flight trajectories, especially in relation to the Earth's ozone layer
- Determining potential means for the **reduction of sonic booms**
- Mastering the complexity of transitions between the aircraft's various propulsion modes
- Finding lightweight materials capable of resisting high stress levels and temperatures during a large number of consecutive flight cycles
- Defining adequate thermal protection and thermal management for the passenger cabin and cockpit
- Evaluating the on-board power generation and storage aspects for hypersonic flight-rated engines that do not have rotating parts
- Assessing the impact on passenger comfort (including standard flight conditions in terms of acceleration, effects of natural cosmic radiation; interaction between the aircraft and pilot; cabin/passenger interfaces; on-board service, and cabin environment management in terms of noise, temperature and humidity).

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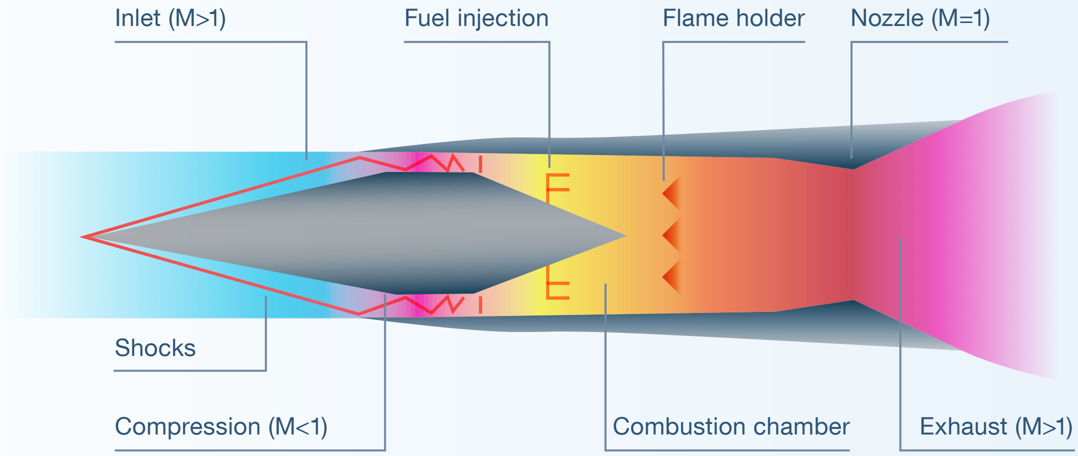
Ramjet Fundamentals

Ramjet engines – which would be used on the ZEHST aircraft for acceleration to its maximum cruise, as well as sustained high-speed flight – have no rotating parts and **use surrounding air for the combustion of the fuel, which can be hydrogen, kerosene, methane, gas or bio-fuel. Fuel consumption is relatively low, which makes it well suited for long-range flights within the atmosphere**. Ramjets produce thrust by passing hot exhaust from the combustion of a fuel through a nozzle, which accelerates the flow. The reaction to this acceleration produces thrust. To maintain flow through the nozzle, the combustion must occur at a pressure that is higher than that at the nozzle exit.

A ramjet's high pressure is produced by "ramming" the air into the combustion chamber using the forward speed of the aircraft. The combustion process inside a ramjet occurs at subsonic speeds. For an aircraft travelling faster than the speed of sound (Mach >1), air entering the engine is slowed to subsonic speeds (Mach <1) with shock waves triggered by the engine inlet's cone. **A ramjet can only produce sufficient thrust when an aircraft already is moving at supersonic speeds greater than Mach 2**. As there are no rotating parts in a ramjet, they are lighter and simpler in construction than turbojets. Ramjet technology can be considered proven for unmanned applications up to Mach 5.



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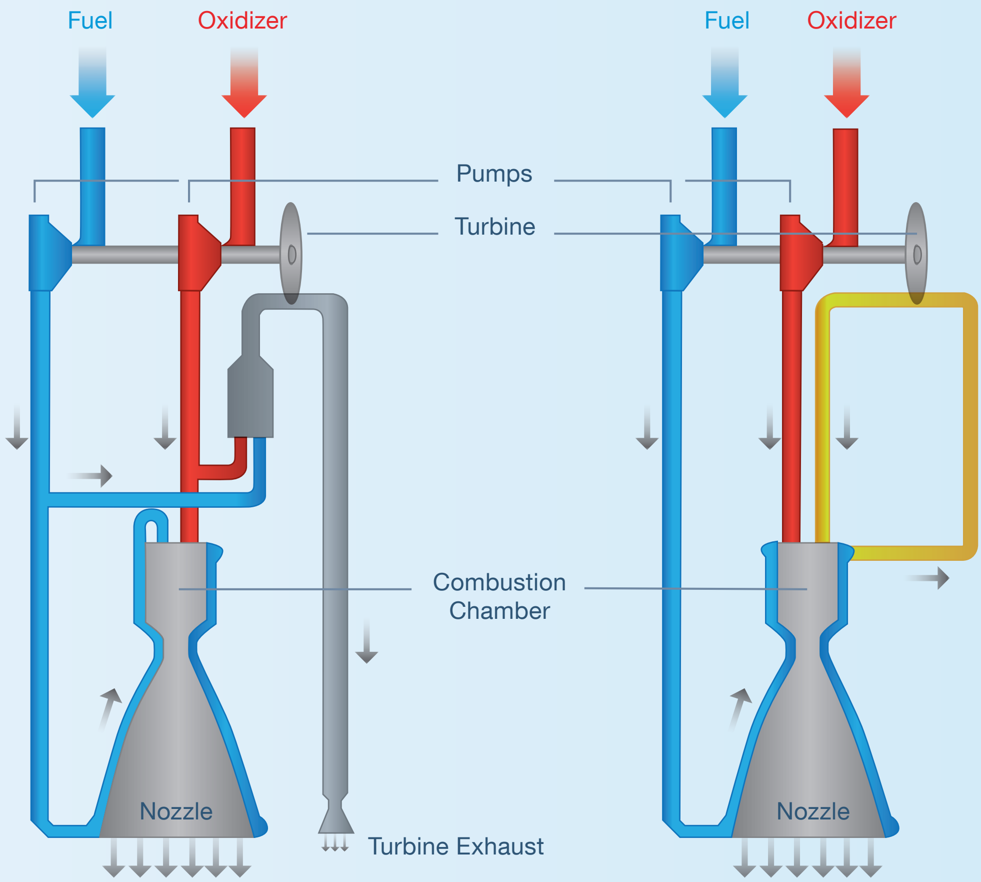
Cryogenic Rocket Engine Fundamentals

The rocket engines for the ZEHST project will be **derived from the types used in the Ariane commercial launch vehicle**. They are to utilise cryogenic (cooled and liquid) hydrogen as fuel and cryogenic oxygen as an oxidizer, each of which are stored in separate tanks. The propellant tanks are pressurized by helium injection supplied from separate high pressure tanks. When the rocket engines are operating, propellants are pumped into a combustion chamber where they are mixed and burned. The combustion produces great amounts of exhaust gas at high temperature (in the range of 2500/3500 K) and pressure. The hot exhaust is passed through a nozzle which accelerates the flow, producing thrust. The engines feature a cooling circuit, where some of the cold propellant is passed through tubes around the combustion chamber and nozzle, enabling them to sustain the high temperatures.

The schematics show a gas generator cycle as in the Ariane 5 launch vehicle's Vulcain engines (below, left). In engine types which draw the energy to drive the pumps from the cooling circuit instead of using a gas generator, the cycle becomes an expander cycle as in the Vinci engine (right), which is under development.

ZEHST's rocket engines will need to be suited for multiple uses in operation. The European space industry's knowledge in the area of rocket engine reusability is based on previous reusable engines and studies performed – for example, within the Reusable Launch Vehicles programmes – giving confidence that this challenging task can be mastered.



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Pursuing Challenging Goals

In addition to its environmental targets, the "Flightpath 2050 – Europe's Vision for Aviation" roadmap addresses customer orientation and market requirements, as well as industrial competitiveness and the need to maintain adequate skills and a research infrastructure base in Europe. It also emphasises that technological leadership will continue to be a major competitive differentiator, and that breakthrough technologies will be required to secure future competitive advantages.

The ZEHST project supports the Flightpath 2050 goals in these respects. EADS INNOVATION WORKS, ASTRIUM and ONERA are using the full extent of their expertise in the global architectures of complex systems through multi-physics optimisation – supported by numerical simulations and coupled with advanced integration in digital mock-ups, collaborative engineering tools and materials engineering disciplines. The partners will make use of their competences in project management with multiple industrial and research institute partners, as well as public agencies, in an international context.

The ZEHST programme has some of its roots in French-Japanese cooperation, beginning when the Groupement des Industries Françaises Aéronautiques et Spatiales (GIFAS) and the Society of Japanese Aerospace Companies (SJAC) signed a Supersonic Technologies Cooperation Agreement during the 2005 Paris Air Show. It was to foster and enrich the relationships between both countries' aerospace industries and it was followed by an EADS proposal to extend this cooperation to a High-Speed Transport Concept Study.

EADS INNOVATION WORKS is the corporate network of research centres of EADS. A highly skilled workforce of more than 700 is operating laboratories that guarantee EADS' technical innovation potential with a focus on the long-term. The network's structure and the teams within EADS INNOVATION WORKS are organised in seven global and transnational Technical Capability Centres:

- Composites Technologies
- Metallic Technologies and Surface Engineering
- Structures Engineering, Production & Aeromechanics
- Engineering, Physics, IT, Security Services & Simulation
- Sensors, Electronics and Systems Integration
- Energy & Propulsion
- Innovative Concepts and Scenarios

ZEHST is one of the projects related to airborne platforms for the next generation of EADS products being managed by the "Transversal Projects and Demonstrators" department within the EADS INNOVATION WORKS' "Innovative Concepts & Scenarios" Technical Capability Centre.

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