Research and Innovation action

BEE-PLANE

Medium range aircraft with detachable fuselage

H2020 Proposal PART B for call topic MG. 1.5-2014

Sections 1 – 2 – 3

List of participants:

Participant no.*	Participant organisation name	Part. short name	Country
1 (CO)	Technoplane SAS	TECH	FR
2	Eurotech SAS	ERT	IT
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Note: ***All the abbreviations, the references and the bibliography used in this proposal are described as Annexes after sections 4 and 5.***

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1.1 Overview

The societal and legislative requirements placed on civil aircraft continue to require innovative solutions in order to reduce travel costs and greenhouse gas emissions. Passenger traffic is projected to grow at a rate of 5% per year. The number of new airports that are currently planned today will not provide sufficient capacity to meet this projected traffic. A step change in air transport is needed, for both passengers and freight, in order to meet these traffic projections.

The Bee-Plane project will develop a new concept in aircraft design, an **aircraft with a detachable fuselage** and demonstrate the beneficial impact on airport infrastructures, ground operations management and air transport system that can be achieved through this design.

A detachable aircraft fuselage enables the management of embarkation and disembarkation independently of flight operations. This type of asynchronous management has proven benefits in traditional land freight operations. With this concept, the ultimate objectives are to decrease the travel and transport costs, accelerate turnaround time and significantly increase in-flight usage of the aircraft by offering several fuselages for the same aircraft. This will also reduce greenhouse gases emissions in the airport area.

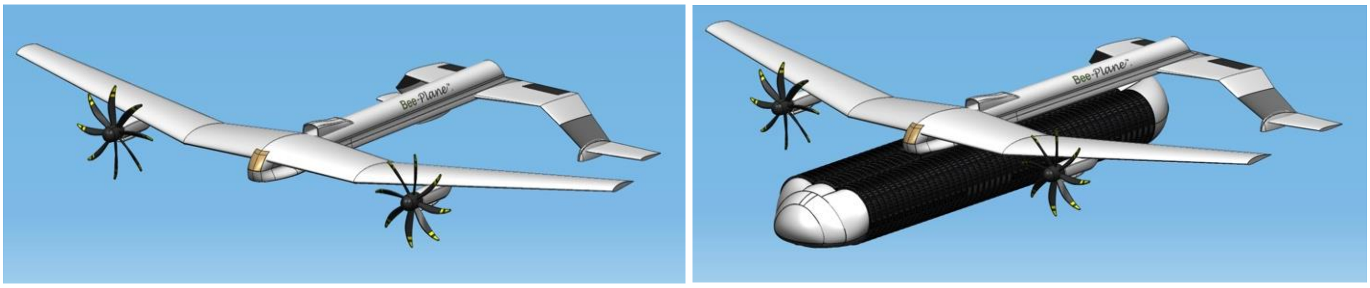

Figure 1: Bee-Plane detachable fuselage concept (Estaca & Supmeca, 2014)

The Bee-Plane project is thus taking a disruptive approach to traditional aeronautic research in order to produce a step change in aircraft and airport operations. The project adopts an open and collaborative approach with partners from academia and industry to develop a concept plane that will develop novel technologies. These have potential to be integrated on more traditional aircraft architectures (e.g. mixed propulsion systems and a triple bubble fuselage design).

An air transportation system such as the Bee-Plane could reduce average travel time across Europe through a significant faster embarkation and disembarkation processes. It should be possible to decrease passenger terminal size by 80%, thus enabling a drastic redesign of passenger hubs with new capacities for easier interconnections with other transport modes such as rail links. With reduced requirements for runway length and airport facilities, the Bee-Plane will also allow additional traffic density in existing regional airports and increased usage of smaller airports closer to urban centres.

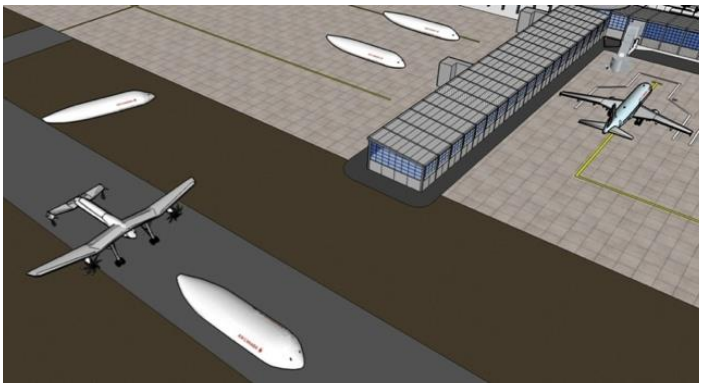

Figure 2: Bee-Plane on an airport

The benefits of the Bee-Plane design were initially investigated through collaborative projects with a number of European universities which have advanced the concept beyond TRL 1. The project will make use of this existing work for the preliminary aeronautical configuration; these studies are available at www.bee-plane.com and the related technical wiki. The initial studies have demonstrated that the benefits of the Bee-Plane include a significant reduction in airline costs. The TRL 1 studies conducted on Lyon-Saint-Exupery Airport (regional passenger hub for Air France) and Clermont-Ferrand regional airport showed a 28% decrease in ticket prices for the Bee-Plane when compared to an Airbus A321 (Echabé, 2013). In response to changing market conditions optimum usage of different fuselage configurations will reduce airline’s operating costs. Several fuselages (the lower cost part) could be exploited with a single aircraft (the expensive flying element), leading to a decrease of the aircraft’s purchasing costs.

The Bee-Plane is currently equipped with a mixed configuration of off-the-shelf engines; namely two low noise turbo propellers for cruise flight in combination with a central rear turbofan for take-off. Optimal use of this engine combination produces a fuel burn below 3L/PAX/100km, a reduction compared to standard aircraft equipped only with turbo propellers or turbofans. This fuel burn reduction is achievable with existing engine technology.

During the course of the project, the Bee-Plane concept will be **maturated to TRL2** as a mid-term project objective and will be **advanced towards critical aspects of TRL3** by the end of the project. Special Interest Groups (SIG) formed by airports authorities and Airline companies, from the beginning of the project launch, will monitor this progress through interviews and presentations of results. In addition the SIGs will provide input to define and target longer term objectives of the Bee-Plane project. The **overall goal** of the Bee-Plane research is to further develop the R&D consortium and establish a partnership with an existing large aircraft manufacturer to enable the production of the aircraft by 2040/2050.

1.1.1 Objectives and Rationale

Passenger traffic has been increasing continuously in recent years with 3.1 billion air passengers in 2013 (source ICAO). The aeronautics industry recently produced a strategic research and innovation agenda aiming at implementing the vision for the Europe aviation system and industry by 2050. As described in this vision, among other ambitious goals, the aviation industry is expected to:

- Offer 90% of European travellers complete door-to-door journey times within 4 hours,
- Provide coherent ground infrastructure, including servicing and connecting facilities, with other transport modes at affordable costs with increased frequency and punctuality,
- Reduce journey times and decrease the costs and risks of the complete transport chain.

Achieving this vision requires significant breakthroughs in the way aircraft and airports are designed and integrated with other transport systems. The challenges to be addressed are:

- Design of an innovative air transport system either by adapting existing airports (to provide services for traditional and novel aircraft) or developing small effective cost airports close to urban centres,
- Provide a reduction of costs while maintaining a high level of services to customers and an increased fleet exploitation time, (i.e. in flight usage of the aircraft),
- Decrease the overall turnaround time for both passengers and freight,
- Meet environmental targets, especially noise and air pollution, as populations move closer to airports.

Bee-Plane can achieve a:

- ***Reduction*** by a factor of 5 in the airport terminal's size,
- ***Reduction*** of up to 30% on ticket price,
- ***Reduction*** of the fuel burn below 3L/PAX/100km.

The Bee-Plane project will address these requirements through the development of a concept **aircraft with a detachable fuselage** addressing the following challenges:

- Completing vehicle feasibility and performance studies,
- Modelling airline costs including acquisition costs, business model and operations,
- Assess the impact on the European air transport system, especially on existing or new airports,
- Define the benefits for citizens and travellers.

1.1.2 Bee-Plane Objectives

The Bee-Plane main objectives are to:

- Define a medium range **aircraft** with detachable fuselage at TRL 2,
- Design **airports and airlines process** for detachable air transport,
- Quantify cost reduction and disruptive **impacts** for sustainable benefits,
- Define the project's **next steps** for future developments (TRL3/TRL4),
- Achieve breakthrough **innovation** in air transport system through the exploitation of the concept at all project stages (i.e. beginning with knowledge transfer to traditional aircraft design).

For each of these objectives, the refined detailed objectives are the following:

DEFINE A MEDIUM RANGE AIRCRAFT WITH DETACHABLE FUSELAGE AT TRL2

The project will define a detailed configuration to achieve an optimised vehicle:

Detailed objectives: aircraft
Specify and optimise a medium range aircraft with detachable fuselage (maximum range 5,000km, full economy capacity 220 PAX), asses the weight in comparison to existing aircraft
Analyse potential safety and certification issues including critical showstoppers (e.g. maintenance issues for the detachable fuselage and fastening system)
Develop a digital model of the aircraft and the detachable fuselage
Design the critical main equipment and perform related mechanical studies, the focus will be on the highly novel elements (main landing gear, locking system and rear landing gear)
Perform structural, aerodynamic, acoustic, mechanical and fatigue calculations
Predict in-flight performance (payload-range, flight stability) addressing in particular any drag issues
Reduce the design complexity (by standardization, commonalities and modularisation techniques) to optimise the maintenance costs

Related work packages: WP1, WP2, WP3, WP4, WP5.

These objectives will be met by:

- Developing aircraft technical specifications including the design of main mechanical equipment,
- Completing basic and detailed aerodynamic, acoustic and mechanical characterisation of Bee-Plane,
- Producing a basic wind tunnel mock-up to be used in UNINA wind tunnel and exploited in numerical models.

DESIGN AIRPORTS AND AIRLINES PROCESSES FOR DETACHABLE AIR TRANSPORT

Detailed objective: airports and airlines processes
Define Business models and economic impact of a potential Bee-Plane-Airport and commercial companies
Create an evaluation methodology for Bee-Plane integration within existing (large and regional) airports to assess new offers of services to travellers against reduced infrastructure and ground operations costs
Set up Bee-Plane change propagation models and mechanisms
Define the main scenarios for Bee-Plane integration in a number of current airport types, including in particular smaller airports e.g. London City Airport, which will facilitate and accelerate travel connections with other transport modes, reduce airport operation costs and reduce an aircraft ground turnaround time to minutes

Related work packages: WP1, WP6.

These objectives will be met by:

- Producing basic models of airport processes and airline operations,
- Designing new processes that could be implemented with the Bee-Plane concept.

QUANTIFY COST REDUCTION AND DISRUPTIVE IMPACTS FOR SUSTAINABLE BENEFITS

Detailed objectives: cost reduction and impact
Prepare key market and performance indicators and the methods to assess them in real situations: • fuel burn/passenger/km, daily usage ratio of aircraft, acquisition and operation costs, airport operating costs including passenger facility charge and passenger comfort evaluation • quality, reliability, flexibility, availability, maintainability, speed/reactivity
Specify key environmental indicators (fuel burn, carbon footprint, greenhouse gases, acoustic footprint)
Define potential impact and operating costs on airport infrastructures. Analyse the decrease turnaround time for the aircraft and design new embarkation and disembarkation facilities and processes
Establish the market impact of such a concept at a European scale including the impact of innovative air transportation services enabling new business models e.g. with aircraft operators different from the fuselage operators or new purchasing strategies (multiple low-cost detachable fuselages with a reduced number of aircraft) to reduce the acquisition costs
Develop a list of potential dedicated fuselage designs including: fuselages with cabins made for different types of passengers or group (low-cost/standard/first class/etc.) or application specific fuselage (hospital, aircraft rescue, firefighting, emergency quick deployment on industrial crisis and environmental disasters, etc.)

Related work packages: WP1, WP6.

These objectives will be met by:

- Producing detailed estimations of the Bee-Plane design benefits for clients, companies and airports,
- Estimating the impact of detachable air transport at European scale.

DEFINE PROJECT NEXT STEPS FOR FUTURE DEVELOPMENTS

Detailed objectives: next steps
Prepare a development and exploitation plan for TRL3 and TRL4
Identify key technologies to be brought to TRL3 and how to develop them
Establish a basic manufacturing and production scheme (supply chain and financial needs) for the complete Bee-Plane project (until TRL9, production phases and operations)
Prepare marketing booklet for future communication in order to extend the consortium's partnership as the concept matures and goes to higher TRL
Communicate with stakeholders through participation at air shows like Le Bourget with the support of professional associations like Normandy AeroEspace, by setting up two SIGs and by developing direct contacts and consolidating existing ones with the industry at large

Related work packages: WP1 and WP7.

These objectives will be met by:

- Estimating returns on investment and requirements to adhere and support such a change in the long term,
- Establishing business models for the Bee-Plane project (including partnership with aircraft manufacturers) for TRL3 and TRL4,
- Producing two display mock-ups (at scale 1/50 for Le Bourget Air show in 2015 and in 2017).

ACHIEVE BREAKTHROUGH INNOVATION IN AIR TRANSPORT SYSTEM

The Bee-Plane project drives innovations in the field of novel aircraft design:

Detailed objectives: breakthrough in air transport system
Identify benefits of Bee-Plane project for academics, SME, aeronautical industries, airports, airlines, countries, etc.
Identifying new technologies which are suitable for transfer to the traditional aeronautical industry (e.g. mix of propulsion systems, the triple bubble fuselage, the tail dragger configuration, airport configuration management etc.) and assess potential exploitation paths
Establish standard economic and technical models to assess Bee-Plane performance compared to fixed wing aircraft
Use this concept plane and enhanced communication, to promote radical innovation in the air transport industry

Related work packages: WP1, WP7, WP8.

These objectives will be met by:

- Development of the concept aircraft with detachable fuselage to TRL2 and preliminary analysis of critical functions for proof-of-concept at TRL3,
- Defining the basis for a future TRL3 project on the Bee-Plane concept with an extended consortium,
- Identification of the key Bee-Plane technologies that can be transferred to more classical medium range aircraft,
- Establishing key parameters used within technical and economic models.

1.1.3 Targeted results

The expected achievements to be assessed and confirmed in the project will be:

Main Achievements	Bee-Plane targeted results
Reduction of travel costs	Average air ticket prices decreased by almost 30%.
Reduction of fuel burn for medium range aircraft	Reach level of 3 L/PAX/100km (with today's existing commercial engines) by changing the overall air transport process.
Reduction of airlines and airports operating costs,	Aircraft acquisition costs reduced by 25% compared with actual regular medium range aircraft (list price of ~67m€).

Main Achievements	Bee-Plane targeted results
aircraft purchasing costs	Reduction of airlines and airports operating costs by 30%.
Reduction of carbon foot-print of air transportation	Establish baseline of carbon footprint regarding total product life cycle and establish a 20% reduction compared to standard today's medium-range aircraft (decrease of the carbon foot print is mainly due to the reduced fuel burn in flight).
Reduction of acoustic footprint of air transportation	Reach noise impact of -3db (shield of the embedded central turbofan with rear tail, increased distance between propeller and fuselage compared to a regular twin engines aircraft, optimised shielding and low noise airframe technologies.
Reduction of environ-mental footprint of air transportation	Decrease material usage (e.g.: metals, metal alloys or composites) by more than 20% for the same level of service compared to regular aircraft (multiple detachable fuselages for one Bee-Plane compared to multiple aircraft, reduced number for Bee-Plane needed for same number of passengers transported).
Development of air traffic on regional and small airports	Estimation of the potential impact of detachable air transportation on a European scale on average traveller time (target 4 hours door to door for any citizen). Confirm landing distance of 1500m by using a slower landing speed. Passenger's terminal size reduced by 80% (no wings on parking slot, only detachable fuselages go to the terminal).
Optimize process and airplane availability	Confirm addition of 2 flights per day compared to a frequent flyer aircraft (e.g.: 6 flights per days) and addition of 3 to 4 flights per days on regular regional lines, taking into account refuelling time and breaks cooling phases.

1.2 Relation to the work programme & action line MG. 1.5-2014

Call challenges/ Scope and objectives	Bee-Plane approach and achievements
Challenge: A number of very ambitious goals have been set by the sector at horizon 2050 in the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council for Aviation Research and Innovation in Europe (ACARE). Many of these goals will not be reached through an evolutionary approach only. Breakthrough innovations are needed, i.e. new solutions which rely on a disruption with respect to current approaches.	The Bee-Plane project represents a new concept in aircraft design. The overall concept does not have any equivalent on the market. It is not an incremental innovation of existing aircraft. As an answer to the needed breakthrough innovations, the proposed solution can achieve ambitious goals set at technical, economic and societal level in the ACARE SRIA. The project started in 2012 within four universities. Consortium grew rapidly to ten European universities, allowing the closure of TRL1 in 2013. First impact studies already show a 28% ticket price reduction for regional flights, with an aircraft using today's existing engines. An industrial approach with a larger consortium is now needed to extend studies to TRL2 and TRL3.
Scope: The proposed research and innovation actions could address the vehicles as well as the air transport system. Regarding vehicles, research and innovation actions could target new technologies and concepts that are not currently used in aeronautics or that have not yet being put in combination in the aviation sector. This could be, for example, radical new approaches to propulsion, to the use of energy, new types of vehicles, etc. Regarding the air transport system, the proposed research and innovation actions could address radical new concepts for the way vehicles,	The concept of detachable fuselage is a radical new approach to the aircraft design with the objective of fostering a radical change in air transport processes. On the vehicle side, Bee-Plane is a complete new medium range aircraft with detachable fuselage. Studies of main innovations will be spread among technical work packages: • Detachable concept (WP1) with an optimized (WP2, WP3) triple bubble fuselage with polyvalent usage, • Specific loading and locking systems, landing gears design (WP4), • Optimised engine selection (two turbo propellers and one central turbofan) with reduced fuel burn (WP1), • Tail dragger configuration (WP3), • Optimal aerodynamic, acoustic, weight and mechanical studies (WP2, WP3 and WP5). On the air transport system side, Bee-Plane is bringing new capabilities for airport processes and airline operations. A dedicated work package will

Call challenges/ Scope and objectives	Bee-Plane approach and achievements
passengers and freight are handled in airports, the type of handling and servicing equipment used, the way airports are organised and connected to other modes, the way information is shared, used and handled on the landside part of the airport. The proposals should aim at demonstrating the validity of the technologies and concepts following a sound technical and scientific approach. The performance should be assessed preferably quantitatively against the relevant criteria such as for example economic viability, time efficiency, safety, potential to cope with evolutions of regulations, passenger friendliness, social acceptance, etc.	focus on impact studies (WP6). Linked with aircraft and concept design (WP1), economic impacts will lead to project next steps (WP7). The main process innovations are: • Accelerating turnaround time of the aircraft, by enabling asynchronous operation (embarkation of passenger before the aircraft actually lands at airport and disembarkation while the aircraft has already taken off), • Reducing overall passenger travel time by integrating regular ground transport modes (train, cars, bus, etc.), security checks, luggage's loading and passenger's embarkation, in a seamless network, • Increasing airports throughput with quicker field operations (asynchronous operations) and shorter landing fields (1500m due to slower landing speed), • Bringing flexibility in passenger and luggage transfer, by avoiding conveyor belt and passengers bridges, • Decreasing operating costs for airlines through reduced fuel burn and increased aircraft performance, • Change airline business model by having technical aircraft operators and detachable fuselage commercial operators, • Improve the ratio between waiting periods (airport, embarkation terminal, aircraft fuselage) and process period (walking, check point, etc.) for passengers. The project will assess overall performance of this detachable concept, including economic and usage criteria.
Considering that a large fraction of air pollution on airports is caused by handling and servicing, aspects of environmental friendliness and energy sustainability should be taken into account.	The project will have positive and non-negligible impacts on existing airports and environment as a whole: • Before the airport: reduce the unproductive and wasteful time and energy requirements of transportation to the airports which are often far from the urban centres. Airports with a smaller footprint due to shorter runways can be used closer to urban centres, • At the terminal: decrease passengers movement and simplify luggage handlings through the design of new adapted processes for smaller terminals, • During servicing: detachable fuselages enable the use of fewer vehicles for catering and reduce handling constraints in comparison to complete regular aircraft positioned at the terminal building, • During aircraft taxiing: reduce energy needs by moving only detachable fuselages on taxiways, not complete aircraft, • During take-off and landing: reduce fuel burn and noise emission with a lower speed and optimised engine operation.
The actions should also assess at the end of the project the potential of the technologies to be developed at further technology readiness levels and barriers that could prevent such developments.	Showstoppers resulting from previous TRL 1 studies (main landing gear, rear landing gear, locking system) will be assessed within a dedicated work package (WP4). During the third year, the critical TRL 3 items resulting from TRL 2 will be identified (WP1). A project development plan, a business model and key market impact indicators will confirm ability to move to a larger industrial consortium for next levels of R&D (TRL 3 & 4). An innovation plan will be established (WP1) to list technologies that could be transferred to more traditional aircraft.

1.3 Concept and approach

The concept for the Bee-Plane was inspired by nature where bees transport pollen baskets back to the hive. However the detachable concept has been investigated previously and a prototype of such an aircraft concept actually flew once in the 1950's thus demonstrating the fundamental technical feasibility.

FAIRCHILD XC-120 PACK-PLANE (1950)

During the 1950s, Fairchild Aviation Corporation developed a prototype, named XC-120, with a detachable fuselage. The XC-120 is a derivative from the freight aircraft Fairchild C-119. The detachable module was approximately 11.3 tons. One test flight was made, but no commercial contract was implemented (Evans, 1950). Patents US2781226 (Fairchild, 1957) and US3361396 (Reno, 1968) describe the detachable configuration. Though the XC-120 proof of concept was achieved, but this aircraft design presented some issues, notably inflight instability, that halted further progress on the project.


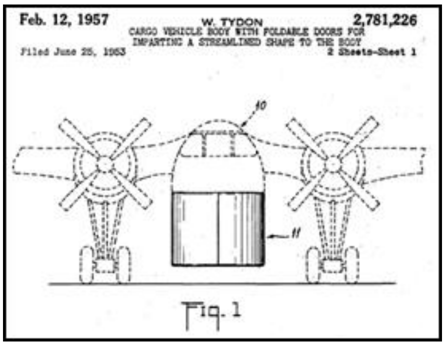

Figure 3: XC-120 Fairchild and Patent US2781226

More than sixty years ago when the Fairchild XC-120 flew, aeronautical technologies were not mature (engines had not enough power, flight controls used mechanical cables, carbon materials and numerical computation were not available, etc.). Aeronautical technologies have advanced significantly since 1950.
The air transport market was in its infancy and airports were not saturated or well integrated with other transport modes. The transport industry was not ready for a modular airplane whereas today's land and sea transport make intensive use cargo container infrastructure. In 1950, the market did not require the advantages of the XC-120 detachable configuration as there was no congestion at airports and it was much easier to produce and operate simpler aircraft. Production capacity was well developed following World War II and at that time, standard aircraft production largely satisfied market needs.

Today, operation conditions have changed:

- Main airports maximal capacities are reached,
- Passenger gateways are overloaded by aircraft,
- Airport taxes represent a large part of ticket prices,
- Operating costs are impacted by higher price of fuel,
- Airport processes and in-flight waiting time represent a large part of overall passenger travel time.

Figure 4: Fairchild XC-120 Pack-Plane (1950)

The current Bee-Plane design is a significant advance of the detachable concept. Existing aeronautical technologies and new market conditions allow us to overcome past technical and economical showstoppers. The Bee-Plane is not an adaptation of an existing aircraft; it is novel configuration specifically designed to operate with detachable fuselages. Bee-Plane project started with an initial TRL0 design and TRL1 project.

BEE-PLANE TRL1 PROJECT (2012-2013)

Bee-Plane project was launch in 2012 to address the core market of aircraft deliveries and passenger air transportation (medium range aircraft). **Bee-Plane is equivalent in capacity to an Airbus A321-200**.

The Bee-Plane project takes its origin from this XC-120 concept but:

- Focus on medium range passenger configuration (full economy capacity of 220 passengers),
- Develops a completely novel design which avoids any compromises resulting from adapting an existing aircraft,
- Exploits state of the art technologies, modern tools materials and flight systems not available at that time.

Studies started from a TRL0 design. This configuration presented a tandem wing, two turbopropellers and a cockpit on side. The motivations for the Bee-Plane design have led to significant technical differences from XC-120. For example the Bee-Plane detachable fuselage is pressurized and not detachable in flight whereas the XC-120 pod was designed to be detachable in flight with a parachute.

Figure 5: Bee-Plane TRL0

TRL1 focused on studies of the vehicle feasibility.

State of the art configurations and the drawbacks of previous concepts have been established. Multiple technical studies have been performed with an initial group of four European universities. Studies started from an aeronautical and mechanical approach so that the main difficulties to be addressed were to:

- Select a stable flight configuration (e.g. additional central turbofan, one main wing), that could prevent a crash after an engine failure,
- Reduce non-added value weight, by improving structural design (one central upper beam, reverse U shape tail, tail dragger configuration, triple bubble fuselage, rear central turbofan, thin fastening system, etc.),
- Select a preliminary engine configuration (two TP400 turbopropellers and one turbofan CFM56-3C1 to fit the targeted weight-performance of the aircraft) in relation to passenger capacity (upper class of the medium range aircraft market),
- Design main equipment and achieve basic material and structural stress analysis,
- Establish project fundamentals, based on collaborative works and aeronautical innovation.

Figure 6: Bee-Plane at end of TRL1

With an eventual consortium of ten universities, research has focused on basic analysis that confirmed the potential beneficial impacts of such a concept. As a result various aeronautical configurations have been evaluated and one optimal configuration has been selected. A specific choice has been made on the engine layout which features a dedicated wing and aircraft configuration designed to eliminate inflight instability issues, such as those encountered by the XC-120. The aircraft flight stability is optimised for solo flight as well as flight with a fuselage by using today's computerized tools to conduct detailed aerodynamic studies. The Bee-Plane TRL1 studies (see http://www.bee-plane.com for details) were officially closed during Le Bourget Air Show in 2013. TRL 2 studies were initiated. The studies achieved during TRL1 identified the optimal configuration of a medium range aircraft with a single detachable fuselage. This is the configuration now selected for advancement to TRL2. Work has now to be extended in order to refine configuration and conduct detailed analysis with existing academic partners and within an extended consortium of technical and industrial companies.

1.3.1 Detailed Bee-Plane TRL2 configuration

Bee-Plane is a medium range aircraft composed of two structures that can be detached:

THE AIRCRAFT

The aircraft is the upper structure above the detachable fuselage. It contains all equipment needed to fly: a regular main wing, two main landing gears below main wing, a tail dragger configuration, rear wings with reverse U shape and one auxiliary power unit. The upper structure can fly without the detachable fuselage. The main landing gear is retractable inside the main wings. Two directional landing gears are located on the tail of the aircraft. Two options will be considered for the cockpit (on the aircraft or within the detachable fuselage).

Resulting from the completed TRL1 studies, the main characteristics of the initial aircraft configuration for the project are the following:

- Maximal Take-Off Weight is 100 tons (including 60 tons of detachable fuselage),
- Maximal range is 5000 km,
- Wingspan is 42 meters, Wing surface is 150 square meters, Wetted surface is 500 square meters,
- Distance between main landing gear is 10 meters, landing distance is 1500 meters,
- Cruise speed between 650 and 700 km/h (compared to 850 km/h for existing aircraft with two turbofans),
- Maximal fuel capacity is 30 tons (10 tons in the detachable fuselage and 20 tons in the aircraft).

Its specific shape allows an innovative engine's configuration composed of:

- Two turbo propellers (typically the TP400 engine of 1.89 ton each[1]) for cruise flight,
- One embedded rear turbofan (typically the CFM56-3C1 of 2.1 ton) for additional thrust on take-off. Central turbofan is not used for propulsion during cruise.

Due to the slower in flight speed, fuel burn is largely reduced compared to existing aircraft with today's engines. Therefore less fuel is embarked for in-flight consumption which compensates for the additional weight of the central turbofan.

Figure 7: Bee-Plane side rear view (Supmeca, 2014)

Complete average traveller time is largely improved due to changes in airport operations and integration with other transport modes. Bee-Plane takes benefit of its innovative concept to reduce overall traveller time, especially on frequent 1 to 2 hours intra continental flight where the additional weight of the detachable concept is largely balanced by cost and fuel reduction. The long range market and larger capacities (where slower speed and additional weight of the fastening system have fewer benefits) are not targeted by this project.

THE DETACHABLE FUSELAGE

The central detachable fuselage contains passengers, freight or a dedicated application. It can be loaded and unloaded from the aircraft without a U-turn directly on the taxiway. The detachable fuselage weight is 60 tons with a length of 32 meters and an outside width of 7 meters. The internal floor surface is 170 square meters with a max capacity of 220 passengers in the full economy configuration. It allows approximately 22 rows of 10 seats with two aisles. Seat configuration is 3-4-3. One cabin for the ground driver is located in the front, with two toilets. A single large galley and two additional toilets are located in the rear. Two aisles ease passenger's embarkation and disembarkation as well as inflight accommodations.

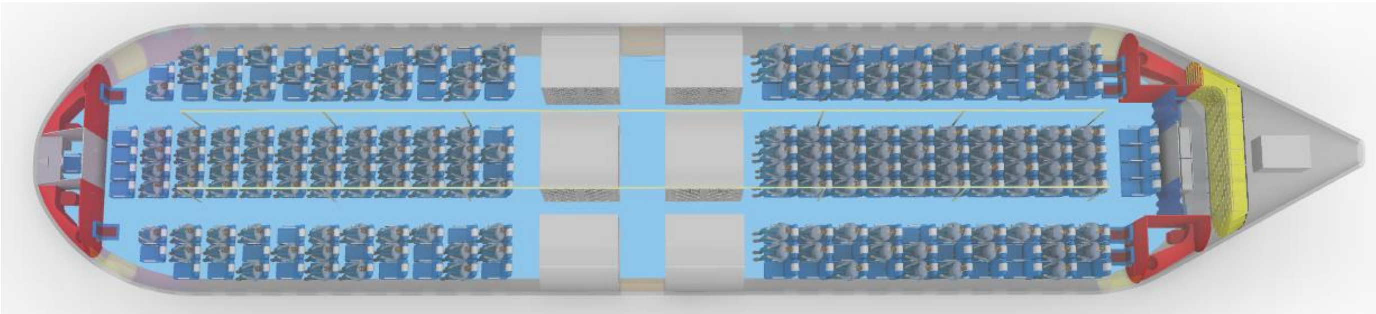

Figure 8: Full economy passenger detachable fuselage (Supmeca, 2014)

Other configurations can be designed by airlines for example; a two class's layout may contain 200 passengers and one additional galley in front.

The fuselage is made of triple pressure bubbles. The diameter of each pressure bubble is 3.2 meters externally. It allows a wider and shorter fuselage with a reduced wet surface, a decrease in skin weight compared to a regular longer round fuselage (A321: 3.95 meters wide, 44 meters long) and an additional lift effect. The volume below the floor allows space for fuel tanks. Additional equipment is four retractable wheels (used only for ground taxiing, not for landing) and an auxiliary power unit. During taxiing, the auxiliary power unit provides electricity for air conditioning, passenger entertainment system and wheels electric propulsion. Shelves for the passenger main luggage are located at same level as passengers (there is no lower deck) reducing the height of the fuselage, the frontal area and the associated drag. Walls of shelves are used as internal structural elements below the locking system to the aircraft. Regular internal reinforcement structures are located along the aisles, every four seat rows, as required by the triple bubble architecture.

[1] Other options will be considered, as the TP400 is a military engine that could be expensive to acquire and maintain. Other options could e.g. to look at a configuration made of four low cost engines Pratt & Whitney PW150A, 700kg each.

1.3.2 *Main technological developments to be made*

During TRL2, on the technical side, the Bee-Plane project will focus on the specification and optimisation of the aircraft and the fuselage for passenger usage, and especially aeronautical, structural and mechanical specifications. Main technological innovations will concern:

- Overall aircraft architecture with a stable tail dragger configuration, that can fly with and without detachable fuselage,
- Development of main landing gears with lifting capacities (for loading/unloading of the fuselage),
- Integration of rear landing gears within vertical tail of the aircraft that will limit drag and allow ground loading operation,
- Design of the locking system between aircraft and detachable fuselage, with air, fuel and electrical quick and secure connection mechanism.

Main studies to be done during the project will concentrate on these main technological innovations and any corresponding potential showstoppers (e.g. structural or equipment additional weight). Impact analysis studies on air transport and airport will be performed in parallel. Technical studies will consequently be the following:

AERODYNAMIC STUDIES

To refine the external shape, aerodynamic studies will be performed with and without detachable fuselage:

- Main wing configuration and characteristics (gravity centre, centre of lift and position of turbo propeller engines, etc.),
- Flight characteristics when flying with or without detachable fuselage,
- Rear wing configuration and impact of engines failure at take-off,
- Drag analysis and external shape optimisation.

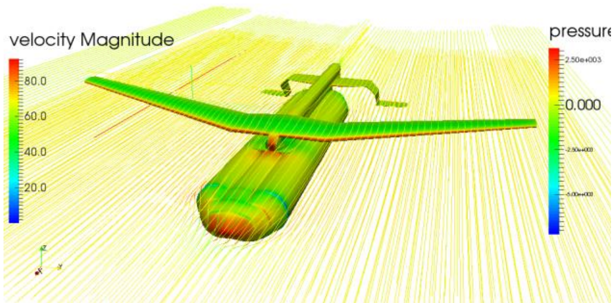

Figure 9: Aerodynamic studies (Supmeca, 2014)

ACOUSTIC STUDIES

To insure that Bee-Plane meets the strategic targets set for future aircraft noise reduction the acoustic footprint of the aircraft has been considered from the initial stage of the design. The acoustic studies will determine and optimise aerodynamic and engine noise by:

- Establishing a baseline noise assessment of the current design for the Bee-Plane in terms of industry standard measures, such as effective perceived noise level (EPNL), assessing the Bee-Plane noise emission in comparison with current commercial aircraft designs outside the aircraft and inside the detachable fuselage,
- Defining modifications to the airframe design for improved noise performance (both external and internal) through enhanced shielding, reduced transmission, low noise airframe technologies, etc.,
- The studies will generate 3D spatialized auralizations of the Bee-Plane fly-over noise as experienced by a ground based observer for use as a dissemination tool.

STRUCTURAL AND MECHANICAL STUDIES

To define optimal structure, the following developments will be made:

- Design of the overall shape of the passenger detachable fuselage with an external skin that is a triple bubble fuselage with internal rows of reinforcement structures,
- Design of the internal structure of the aircraft (fuselage and wings, design and materials) with minimal weight,
- Characterise and reduce sources and tendencies of main vibration and structure resonance, especially in rear tail (that supports rear directional landing gear).

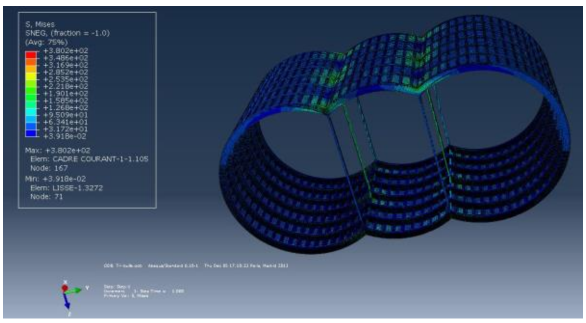

Figure 10: Detachable fuselage internal structure (Estaca, 2014)

The weight of the aircraft will be specified more precisely, allowing detailed analysis on fuel consumption and aircraft passenger capacity.

To find optimal mechanisms and structures additional studies will focus on:

- Mechanical studies at landing situation, especially on main and rear landing gears (including position and structural requirements),
- Behaviour of fasteners and connection mechanism (elastic limit compared to maximal acceleration phases),
- Unexpected situation such as non-opening of the landing gear,
- Static and dynamic aero-elastic stability.

IMPACT ANALYSIS

Impact analysis will be performed on:

- Airline costs:
  - Fuel consumption according to multiple flight conditions and loading scenarios,
  - Operation costs, taking advantages of the detachable fuselage concept,
  - Purchasing costs and return on investments, compared to regular aircraft.
- Airport economic impact (regarding size, location, usage):
  - Adaptation and re-organisation of existing infrastructures and facilities,
  - Design of new terminals with dedicated operations and processes for ground operations.
- Air transport system:
  - Development of airports usage (smaller terminals, closer to city centres, facilitating connection with on the ground transports),
  - Separation of aircraft's technical operators from detachable fuselage's commercial airlines,
  - Definition of new business models that potentially lead to an overall industry having some similarities with the container industry (rental, cross-docking, multi-usage containers, etc.),
  - Impact of the detachable concept at a European scale for European medium range air transport.
- Environment:
  - Noise impact on the ground, air pollution estimate, material usages during production process.
- Passenger acceptance:
  - Analysing the acceptance of traveling in a detachable fuselage by passengers and potential barriers, notably psychological ones.

1.4 Ambition

A WORLD WITH BEE-PLANE

July 2050, you are preparing your holidays. You are flying to the south of Europe, visiting friends. You think back to the beginning of the century, when you had to go to Paris to catch a plane. Living in Normandy, France, you had a two and half hour drive to the main airport and one hour of additional wait-time (parking, walking and waiting). Rouen's regional airport, thirty minutes from your doorstep, now proposes regular flights to all frequent European destinations. Ticket prices and airport taxes have been greatly reduced as detachable air transportation has become the standard. You still see fixed-wing aircraft used for international flights, but they are now parked very far from the new passenger terminals.

Immediately following security check, you enter the plane (detachable fuselage), drop your luggage, rest for a while and enjoy the services proposed on board. This time, you did not go low cost; you made a reservation on a premium airline which provides you with additional rest areas and shops on board. Boarding has just finished, the crew team invites you to be seated, while the fuselage taxis to the loading place. The plane just landed and it is time to take-off. You feel the little knock when the aircraft loads the fuselage and you know that the locking system is securing the attachment. You remember your first flight on a detachable plane and your initial fear of the pod detaching in flight. Your uneasiness vanished years ago when you read that detachable planes are actually safer. It was even proven that, as pilots spend less time on useless ground operations, human errors in flight decrease.

All over the world, up-and-coming airlines operate solely detachable airplanes to cope with the rapidly increasing traffic. The aeronautical industry has continuously contributed to European exports, triggering a rise in living standards. Manufacturing of value-added aircraft and the production of high value detachable fuselages have expanded the European aviation industry and enabled a host of new businesses to generate employment. Furthermore, the decrease in air transportation prices linked with the reduction of travel time has increased European competitiveness and improved integration of companies and services that benefit the real economy.

While flying, you do not even notice engine noise, as the main turbofan was shut off a few minutes after take-off. Lying back, you marvel at how detachable transport has transformed air transportation. The Bee-Plane became the poster child of successful projects initiated by European Funds, adopted by the aeronautical industry and delivered to European and global customers. Once again innovation was the key to Europe maintaining its industrial leadership.

1.4.1 State of the art

The Bee-Plane design represents a complete step change in air travel, airport infrastructure and airline operations. However this highly novel design builds on past studies on similar concepts in aircraft such as large flying wing aircraft and cargo helicopters with detachable modules. The following sections review these current and previous aircraft designs and demonstrate the advances achieved through the Bee-Plane. The benefits of the drastic change which could be achieved through airport operations and transport integration are described in the impact section.

LARGE FLYING WING WITH DETACHABLE PODS

Several projects have investigated potential designs for large flying wings with varying numbers of detachable pods. The Clip-Air project from EPFL (see (Bierlaire, 2012)) and the Configurable Air Transport (CAT) project from US Air Force Laboratory (see (Snead, 2005)) produced designs of large flying wings with three detachable fuselages.

The Clip-Air modules have a capacity of 150 passengers each. The aircraft can hold 1, 2 or 3 modules during flight. This is comparable to an Airbus A320 (150 seats), an Airbus A330 (293 seats) or a B747-200 (with 452 seats). “When transporting one capsule, the aircraft is 78% heavier than one A320 plane, but when transporting three capsules, overall aircraft is 11% lighter than three A320” (see (Bierlaire, 2012)).

The CAT design is assumed to be capable of transporting over a distance of 9 500km three modules or one central large module.

Figure 11: Clip-Air flying wings with detachable fuselages (EPFL, 2012)

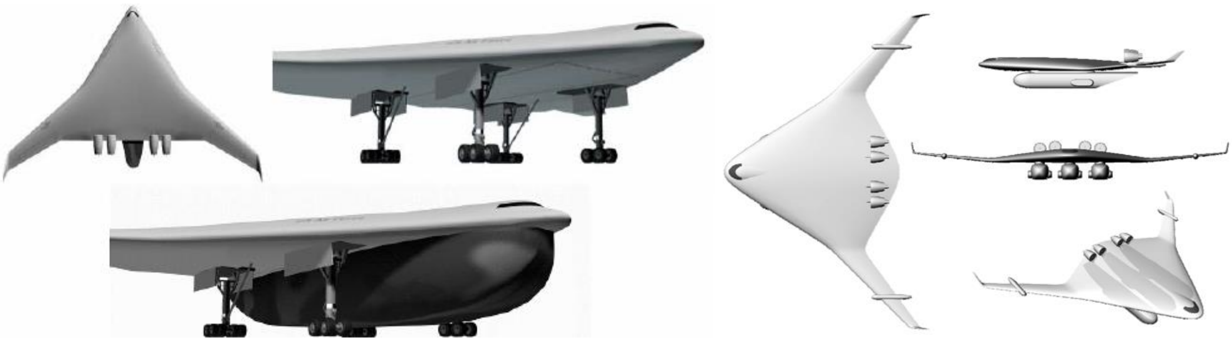

Figure 12: CAT large flying wings with 2 versions of detachable pods (Snead, 2005)

The initial CAT gross weight is about 372 tons, wing span 85.3 meters. Modules are 45.7 meters in length and 5.8 meters in height (see (Snead, 2005)). Patent US6102332 (see (Haxton, 2000)) also describes a large flying wing with multiple detachable pods.

The Bee-Plane TRL1 studies (see above) showed that existing airport taxiways do not allow the operation of an aircraft with such a large width between landing gear. The Clip-Air and CAT projects considered the logistic improvements possible by increasing passenger capacity and aircraft scale. But both projects need large modifications to existing ground infrastructure (extended taxiways) and resulting in comparatively larger infrastructure investments. The Bee-Plane project focuses on a smaller capacity (220 passengers) a shorter flying range (5 000km) and a regular main wing configuration. **A key aspect in the Bee-Plane project is that, contrary to sigthese concepts, at first, only small changes should be implemented on airport facilities.** In particular, the distance between main landing gear should be less than existing large aircraft (12 meters for the Airbus A380, 10.6 for the Airbus A350, 10 meters for the Bee-Plane and 7.59 meters for the Airbus A321). Furthermore, the Bee-Plane could be operated in existing airports by using first floor access to traditional passenger terminals.

RELATED CONCEPTS WITH DETACHABLE FUSELAGE

As part of the vision of the future, Airbus is also exploring similar concepts with an aircraft pod (see Airbus, 2011). However the loading of the pod is not presented.

The Bee-Plane configuration includes: only one main passenger large gate on each side, triple bubble architecture for optimal links with fastening system, no main external equipment attached to the detachable fuselage (e.g. rear tail is on the Airbus pod).

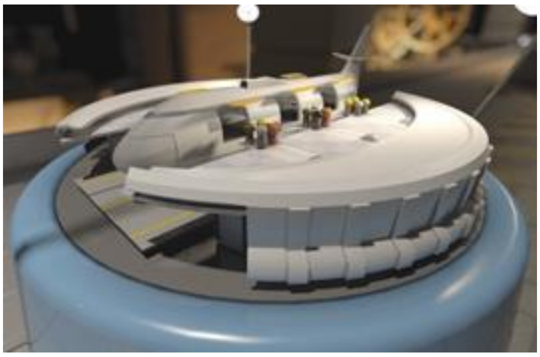

Figure 13: AIRBUS aircraft pod concept

WHITE KNIGHT TWO AND ITS DETACHABLE SPACESHIP

White Knight Two is a cargo aircraft whose design has been dedicated to the transportation of SpaceShip Two, another aircraft module. It is in essence a suborbital space launch system. The central detachable space vessel weights 16 tons and is detached during flight. White Knight Two made a series of flying tests since 2010 and with SpaceShip Two since 2013 (see a video of a flight on Virgin Galactic web site).

The Bee-Plane detachable fuselage is approximately four times heavier than the Spaceship Two capsule. The Bee-Plane fastening system is spread along the fuselage length. Constraints are reduced in each lock of the fastening system, within the central beam and inside the fuselage skins.

Figure 14: White Knight Two from Scaled Composite & Virgin Galactic

Different locking systems have been studied during TRL1 showing that existing materials and mechanism can be used on the Bee-Plane project.

HELICOPTERS WITH DETACHABLE MODULES

Similar detachable concepts already exist within helicopters. The Sikorsky Skycrane is capable of loading a multi-usage container with a payload of 9 tons. A Russian helicopter, Mil-mi10, has the same architecture and a 15 tons maximal payload.

Figure 15: Skycrane S-64 from Sikorsky

They have been initially developed for military applications and are now mostly used for specific civil freight transportation and water bombing in firefighting operations. The modules sizes are much smaller than the Bee-Plane’s capacity and the range of a helicopter is not suitable for economic passenger transportation on medium range distances, particularly due to the small passenger numbers possible in these aircraft.

OTHER FUTURE AIRCRAFT PROJECTS

Mainly initiated by aircraft manufacturers or research organisations, detailed studies of new concepts for future aircraft are hard to find for confidentiality reasons. A summary achieved with academia and industry, in October 2008 by NASA, identifies known design and shapes. This report includes large flying wings and rhombohedral wings. Those designs are not new and their advantages and drawbacks are already known.

For better energy efficiency, the general consensus is that commercial air transportation will need:

- "Slower cruising speed, at about Mach 0.7, or seven-tenths the speed of sound, which is 5 to 10% slower than today's aircraft, to save fuel.
- Engines that require less power on take-off, for quieter flight.
- Shorter runways - about 1900 meters, on average - to increase operating capacity and efficiency.
- Smaller aircraft - in the medium-size class - flying shorter and more direct routes, for cost-efficiency.
- Improvements in air traffic management.
- Lightweight composite structures, engine materials improvements, and better aerodynamic modelling."

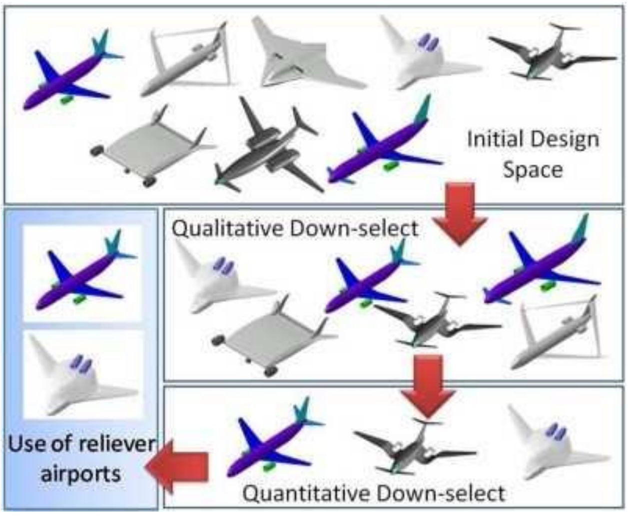

Figure 16: Aircraft advanced concepts (NASA, 2008)

Compared to other future aircraft projects, Bee-Plane is targeting those objectives with the additional technology of having a detachable fuselage. The result of this approach is that a performance step change is possible. Progress on the vehicle, on airport processes and on airline costs will be refined during the TRL2 studies.

1.4.2 Progress beyond the state of the art

Progress beyond state of the art will be accomplished and formalized according to the project main objectives:

DEFINE A MEDIUM RANGE AIRCRAFT WITH DETACHABLE FUSELAGE AT TRL2

Evolving from an idea developed in 1950 with the Fairchild XC-120 prototype the Bee-Plane project is focusing on the aeronautical feasibility of a medium range aircraft with a single detachable fuselage. Apart from large flying wings with three detachable capsules, few modern studies have been made on similar concepts. No studies have focused on the medium range market with a passenger capacity of approximatively 200 to 220 passengers. Today and for the next decades it is projected that aircraft deliveries will mainly focus on this market segment. Within Bee-Plane a detailed technical and economic analysis will be conducted in order to check if market and production performance could be drastically changed by introducing this breakthrough innovation of having a detachable fuselage.

For specific fuselage modules with targeted uses (quick deliveries, emergency aid, crisis support, high value freight, etc.) a worldwide market of more than one hundred aircraft per year is realistic. The Bee-Plane project focuses first on a detachable aircraft for passenger transportation with higher number of deliveries, higher market penetration rate and much higher overall economic and social impact objectives.

To reach those ambitious targets and make progress on the technical issues, studies will focus on the vehicle (in work packages WP1, WP2, WP3, WP4 and WP5), i.e. a medium range aircraft with one detachable fuselage and related issues:

- **Drag issues**: a dedicated work package (WP2) will focus on aeronautical parameters, including drag. Drag will be compared to standard aircraft. After having digitally modelled the complete aircraft, parametric studies will be conducted on partial configuration. Interaction between aircraft and detachable fuselage will be refined to focus on the additional drag introduced by the detachable system. Results will be taken into account within the conception loop to optimise the aircraft shape (WP3) and the design of the interface between fuselage and wings (WP4). Bee-Plane design (WP1) will benefit from this study in terms of the specific shape (high wing, shorter and lower fuselage, embedded turbofan engine) to reach optimal aeronautical configuration.
- **Noise footprint**: Work package WP2 will also produce a holistic study of the aircraft noise. The specific configuration of the Bee-Plane introduces potential new acoustic noise sources (locking system, size of the landing gear, aerodynamic noises between the aircraft and the detachable fuselage). An optimisation of the airframe for low noise performance therefore has to be conducted. The baseline design of the aircraft includes features which can be utilised for low noise component design such as the tail dragger configuration that can be utilised to shield the embedded turbofan, the embedded turbofan is also an advanced low noise feature, lower take-off and landing speed reduced landing gear and aerodynamic noise, reduced structure borne vibrations is possible due to a separation between the upper aircraft and lower

detachable fuselage, reduced interior noise level is possible due to a decrease of the wet surface of the detachable triple bubble fuselage compared to regular round fuselage.

- **Overall weight reduction**: Work packages WP3 and WP5 will focus on the structure and mechanical simulation of the aircraft and its detachable fuselage. A first complete aircraft structure (WP3) will be defined and used for mechanical simulation (WP5). Results of simulation studies will be used within the conception loop in WP1 to refine aircraft configuration and structure design (e.g.: main wings internal beam, internal pressure relievers, rear central fuselage, engine's mount, door positions, etc.). The locking system (WP4) and the specific aircraft detachable configuration (lifting capacities) will add approximatively 10 tons compared to a standard aircraft (Airbus A321). Studies need to show that Bee-Plane will benefit of its specific configuration to reach an optimal weight (multi-bubble fuselage, high main wing, internal reinforcement structure below main wing, external main landing gear rotation). Overall weight of the system will be estimated in more details and compared to regular aircraft. Following TRL1 studies, technical specifications must be refined in order to take into account new materials and an adapted structure. The impact on fuel consumption will then be assessed (WP1) to demonstrate the benefit of optimizations accomplished during the TRL2 project phase.
- **Energy issues**: The new capabilities offered by the Bee-Plane design have a direct positive impact on energy needs, for example: slower flight speed, fuselages tailored to specific operational needs or ground operation of detachable fuselage without the entire aircraft. The detachable configuration has also new energy requirements (additional auxiliary power unit within detachable fuselage to generate on the ground air conditioning, fuel distribution between aircraft and detachable fuselage, additional weight of locking system and main landing gear, etc.). The project will study the overall energy consumption of the aircraft and its detachable fuselage throughout the entire aircraft operation process in order to specify the detailed needs. Those energy studies (conducted in WP1 within the conception loop: first assessment, detailed reviews, then optimisation steps) are directly linked to the required main equipment (WP4) and overall weight of the aircraft (WP3). The overall Bee-Plane project will select the configuration that will lead to an optimal performance change. Energy and fuel consumption are key in the overall economic model of the project. An optimal configuration will lead to lower energy demand and hence to lighter aircraft (smaller engines, smaller equipment and lighter structure) or a related increase in passenger capacity.
- **Safety issues of critical main equipment**: the locking and attachment system is the critical item that is introduced compared to a regular aircraft design. TRL1 studies already show that existing materials and mechanism are sufficient to be used in Bee-Plane locking system. Detailed mechanisms have not yet been studied. Multiple issues will be investigated through various scenarios such as single or multiple lock failure, non-opening of landing gear and related impacts in the structure and locking system. Landing loads and the hard landing situation will be studied in detail in WP4 and WP5.

DESIGN AIRPORTS AND AIRLINES PROCESS FOR DETACHABLE AIR TRANSPORT

Airports are designed and built to take into account the technical needs and requirements of numerous stakeholders (e.g. national and international public authorities, national and international standards, neighbouring cities) as well as economical aspects. It is therefore, necessary to fully respect these specifications when considering new parameters regarding the characteristics of Bee-Planes, in particular their dimensions and the short take-off and landing distance required (targeted at 1,500 meter long to be able to land in London City Airport).

The parameters affected by the adoption of Bee-Plane are the followings:

- Speed: Due to the integration of low noise design from the conception of the Bee-Plane and thanks to short take-off and landing distances airports can be smaller and consequently closer to urban centre. This allows faster multi-modal transportation networks linking both passengers and freight to the airport.
- Cost: The reduced size of the airports ensure less expensive infrastructure required for faster flow of passengers as well as goods transfer to rail and road networks.
- Flexibility: Bee-Planes are by design a configurable aircraft with the possibility of purpose built fuselage modules for emergency situations, firefighting, humanitarian aid, or VIP suites. This flexibility also allows landing on under developed or partly damaged airports.
- Quality of service: The overall quality of the provided service by Bee-Plane on the medium range market is expected to be higher than existing aircraft. Costs are reduced, maintenance operations are easier, manufacturing time is reduced and operating cycle time is accelerated.

- Service Dependability: Flight connections between smaller cities reduce the number of steps for passengers and goods transfer. As fewer transportation services are used the resulting servies will be more dependable. In fact, at each step of a transfer, random events (system failures, planning alterations, strikes, etc.) can decrease the service quality for the global transfer schema. By reducing the number of connections the overall service quality, and therefore the dependability, will increase.

Besides, these parameters, the adoption of Bee-Plane will also introduce additional changes on the airports' operations and design. The density of passenger gates in the terminal should be increased due to the smaller space required for embarking and disembarking. This means that the service area aroung the detachable fuselage has to be redesigned to allow safe and secure operational activities resulting in better space-sharing of tarmacs. The passenger embarking and disembarking processes and their luggage handling will be adapted to these smaller areas ensuring damage-free and safe movements. The spatial configuration of today's airports results in very high energy-consuming buildings. Airport infrastructures could be redefined towards the Bee-Plane concept through design based on sustainable principles and notions of adaptability and modularity (controlling budget, space consumption, renewable energy, etc.). The project will define the main and general guidelines of this new type of airport and the study will develop and achieve two main scenarios:

- To incorporate Bee-Planes with minimal impact on existing airport infrastructure and to permit the mixed-use of traditional aircraft and Bee-Plane simultaneously,
- To increase yield of human's air transportation and airfreights.

These modifications have direct impacts on the ground processes and operations that have to be designed to minimize passenger waiting times and luggage handlings. The following main classes of operations will be designed, modelled and optimized:

- Technical processes:
  - Separation and fastening of the detachable fuselage and the aircraft,
  - Detachable fuselage and aircraft routine check.
- Bee-Plane servicing:
  - Detachable fuselage servicing (refuel, catering, toilettes, cleaning, etc.),
  - Aircraft servicing (refuel, pilots' catering, toilettes, cleaning, etc.).
- Passenger servicing:
  - Disembarking with luggage (handling of luggage by passengers with or without ground operators),
  - Airport entrance and exit formalities (police, toll, security checks, etc.),
  - Embarking with luggage (handling of luggage by passengers with or without ground operators).

All these aforementioned processes must be validated by airport, air transport, air companies and aviation authorities following the investigations in these initial studies.

QUANTIFY COST REDUCTION AND DISRUPTIVE IMPACTS FOR SUSTAINABLE BENEFITS

The project will offer cost-effective services to passengers/customers, airports and their supply networks with fine-tuned sustainable benefits. To reach these targets, a Business Process Integration Methodology, BPIM in short, will be designed in work package WP6. The goal is to allow the main actors and stakeholders to have in their hands a set of realistic scenarios for their infrastructure, business and the services they offer or receive. BPIM will support decision-makers to choose the most relevant Bee-Plane integration scenario for the airport hosted by its economic and social network of actors. The BPIM contains analyses and design methods and tools:

- Bee-Plane integration scenarios: Taking account the main parameters such as annual traffic, future market share, locations of the airport and also the space layout of the airport, the most plausible scenarios of Bee-Plane integration (full economy configuration, two classes, multi-classes, business only, passenger and fret, full fret, etc.) will be defined together with the ground actors. These plausible integration scenarios will be compared with fixed wing aircraft scenarios.
- Bee-Plane change management: The plausible integration scenarios have to be assessed in terms of their impacts on the airport and its hosting economic and social environment. These assessments will be possible by relying on the assessment and techniques (i.e. change propagation mechanisms and demonstrator, performance benchmarks) to be done in the project.

The development of the BPIM will be possible by reaching theoretical developments that have to go beyond of the state-of-the-art in the following fields:

- Change modelling techniques (Eckert et al. 2004), (Eckert et al. 2005), (Jarratt et al. 2011) applied to complex systems with very long time service duration (airports and their environment).
- Change propagation mechanisms and impacts assessments: Following the Forrester effect, the changes could generate an avalanche of unpredictable effects putting in danger the viability of the whole project. Being able modelling dependencies by identification and assessing the change impacts are the key research challenges (Zolghadri et al., 2014).
- Business models: Return on investment and profitability of the integration scenarios have to be estimated thanks to methods and tools to be developed specifically for BPIM.

DEFINE PROJECT NEXT STEPS FOR FUTURE DEVELOPMENTS

The manufacturing and production scheme (supply chain and financial needs) is critical for the complete Bee-Plane project. Here, the idea is not to identify specific companies within the supply chain but mainly focus on the technological capabilities, know-how and expertise of a set of first and second tier suppliers for a consortium of Bee-Plane manufacturers. A deep study of the Bee-Plane architecture and equipment will be done in order to define the main drivers of make-or-buy decisions for a low-cost full passenger configuration. The modules to be developed will be identified while defining the main technical and technological interfaces with acquired modules. Based on this analysis, the main schema of a realistic manufacturing and supporting supply chain of Bee-Plane will be set up. Work packages WP1 and WP7 will focus on those tasks:

- Draft a development and exploitation plan for TRL3 and TRL4.
- Identify key technologies to be brought to TRL3.
- Prepare marketing booklet for future communication in order to extend the consortium's partnership as the concept matures and goes to higher TRL.
- Communicate with stakeholders including participation to air shows like Le Bourget with the support of professional associations like Normandy AeroEspace.
- Define benefits for future academics, aeronautical industries and SMEs.
- Set up two Special Interest Groups – one for Airlines and one for Airports – to gather requirements from these stakeholders and exchange information with them to refine the concept from a business perspective.

ACHIEVE BREAKTHROUGH INNOVATION IN AIR TRANSPORT SYSTEM

Bee-Plane's short term goal is to generate technical innovations and create disruptive developments in the field of aeronautics by targeting ambitious goals of approximatively a 30% decrease in cost, in fuel burn (with today's engines) and in acoustic footprint. As a "concept-plane", Bee-Plane also focuses on useful aeronautical innovations and methods that can be derived from its core studies and benefit the current aircraft industry. Benefits of the project do not only come from the overall aircraft design (expected production time frame is approximatively 2040/2050 following a high level of investment). Starting today with these first steps and technical studies, the project can already generate benefits. It brings new knowledge in the field of future aircraft design and aeronautical technologies.

In general, future aircraft projects are initiated by aircraft manufacturers or large organisations. Contrary to those projects, Bee-Plane uses enhanced communication to openly share innovations and tasks among partners. Multiple academic partners have been involved since the beginning of the project, allowing open innovation and a disruptive approach. A community focused on new aeronautical technologies is being created through Bee-Plane project. Selected innovations need to be studied in more details (e.g. triple bubble fuselage, mix of propulsion, quick aircraft aerodynamic simulation, tail dragger configuration, airport process simulation, etc.). If successful, those disruptive innovations could then be transferred to more traditional aircraft architectures. Work package 1 will establish an innovation summary throughout the project to focus on breakthrough innovations and aeronautical technologies, as:

- **Triple bubble fuselage**: no public study exists on triple lobe architecture. This configuration is optimal for passenger's rows of 10 seats with two aisles (3-4-3). Internal reinforcement structure every 4 seats allows pressure forces to be spread longitudinally among the skin of the fuselage. Width of the fuselage is approximatively 7 meters and height of each bubble is less than 3.2 meters. Drag of the fuselage is reduced due to the lower height of the fuselage compared to a double deck fuselage (fret and luggage's below main deck). Air-cushioned fuselage shape increase lift by better guiding air flow at the bottom of the fuselage. Weight of the fuselage is reduced, due to a reduction of fuselage length and a relative lower increase of the width. Literature exists on double lobe fuselage (e.g.: Patent US4674712, MIT study for NASA (Greitzer, 2010)) and large fuselage (e.g.: Patent US2011220758, EP1332961), but no studies exist on this specific triple bubble fuselage. TRL2 studies will developed this technology on detachable fuselage of Bee-Plane. Innovation summary will also assess benefit for a regular aircraft (main wing and fuselage not detachable) to have a triple lobe fuselage.

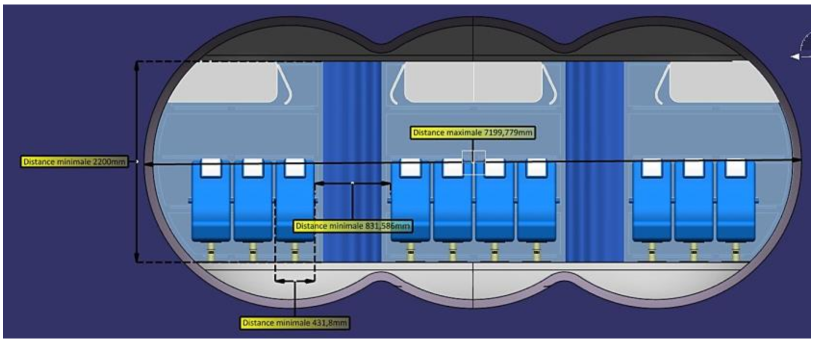

Figure 17: simple deck tripple bubble fuselage (Supmeca, 2014)

- **Mix of propulsion**: The Bee-Plane engine configuration consists of two turbopropellers and one central turbofan. This mix of engines can easily be implemented on regular aircraft and the proposed studies will provide fuel consumption estimation in order to assess benefits of this design. The Bee-Plane shape (rear top central fuselage) is optimal for use of a central rear turbofan which will have additional benefits for noise shielding. Regular aircraft might also benefit from this unusual engine configuration. A central rear turbofan already exists on some aircraft (YAK42, TU154, B727-200, DC10, Hawker-Siddeley Trident, Lockheed Tristar, etc.) but it was not used in conjunction with two turbopropellers on the main wing. Only one prototype has been developed with a mix of engines (Boeing XB-47D in 1955). No modern studies have been conducted on the following specific engine's configuration: two turbopropellers for cruise flight and one central turbofan for additional thrust during take-off or landing phases. Additional weight of the turbofan is balanced by fuel consumption reduction during cruise flight. This innovation will be studied in detail for the Bee-Plane configuration and potential impact of this innovation on regular aircraft will be established.
- **Simplified rating models for aircraft projects**: The project focuses on the impact of the detachable concept on the air transport system. Technical and economical parameters are becoming increasingly complex to analyse. No simple and public methodology exists to compare future aircraft projects to existing aircraft. The project will develop basic model to assess Bee-Plane performance and integration to air transport system. Rating models will be used with grades and weight criteria. The project will extend those models to be able to be used by other projects developing future aircraft. Methodology and criteria will be made public on Bee-Plane wiki. For example: exact definition of low TRL levels for a complete medium range aircraft project varies among industrials, impact of airport infrastructure integration is considered differently when presenting a large flying wing or a medium range aircraft, aircraft aero dynamical stability and structural weight are critical project gates. Existing model will be considered (such as "Enhanced Technology Assessment for Future Aircraft" by DLR). A simplified rating model to assess Bee-Plane performance compared to fixed wing aircraft will be developed and published.

2 Impact

2.1 Expected impacts

2.1.1 Expected impacts set out in the work programme under MG. 1.5-2014

MOBILITY FOR GROWTH 2014-2015
Transport is on the brink of a new era of "smart mobility'' where infrastructure, transport means, travellers and goods will be increasingly interconnected to achieve optimised door-to-door mobility, higher safety, less environmental impact and lower operations costs.
MG.1.5-2014 Breakthrough innovation for European aviation
A number of very ambitious goals have been set by the sector at horizon 2050 in the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council for Aviation Research and Innovation in Europe (ACARE). Many of these goals will not be reached through an evolutionary approach only. Breakthrough innovations are needed, i.e. new solutions which rely on a disruption with respect to current approaches.
Expected impacts according to work programme
Actions will demonstrate their potential to mature the TRL in the range 1-2, to prepare the ground for future highly innovative breakthrough products and services for European aviation which will contribute to decrease the environmental impact, enhance the competitiveness, the mobility and the levels of safety. Actions will also provide ad-hoc indicators to evaluate the potential improvements that the breakthrough technology / concept is capable of bringing, using realistic hypothesis and scenarios.

Bee-Plane is a disruptive and novel design for the future air transport to be achieved by 2040/2050. Bee-Plane will address several aspects of challenge 1 “Meeting societal and market needs”, challenge 2 “Maintaining and extending Industrial leadership” and challenge 3 “Protecting the environment and the energy supply” of ACARE SRIA. The following impacts and links with ACARE SRIA will be made possible:

DISRUPTIVE AIRCRAFT CONCEPT AND TRANSPORT PERFORMANCE STEP CHANGE

In terms of aircraft architecture, the main impact will be the possibility to differentiate and consider the aircraft independently from the fuselage. A key benefit of such a split is the increased flexibility. This will allow the research, development and industrialisation of the two concepts to be undertaken separately:

- The aircraft itself could evolve with improvement of the aerodynamics, materials, engines, weight, systems, etc. to better address operating costs, environment or maintenance requirements. It could also evolve to handle different types of fuselage with different weight, size or usage. These evolutions could be achieved without changing existing fuselages thereby securing the investment of the fuselage’s owners.
- Alternatively, a new fuselage could be developed for passenger, freight transportation or for dedicated applications independently of the aircraft itself.
- The aircraft could transport in the same day, various multi-usage detachable fuselage for different clients without any change to the aircraft configuration. The company owning the aircraft can consequently optimise the usage of the aircraft according to the demand.
- The fuselage operator could look for the most attractive services among different aircraft operators to optimise transport costs and services with a detachable fuselage configuration.

As a consequence of this new operating mode, for an equivalent number of passengers transported, the number of aircraft is reduced. One aircraft could be allocated to several fuselages. Fuselages could be built and configured according to market demand and be operated accordingly. This flexibility (ownership, operations, maintenance) will improve the competitiveness of the sector with more specialised actors. Customised services according to different user requirements provide better operating and marketing costs.

This is a parallel to the proposed approach found in the way current tractor-trailer trucks are used. In this proposed vision for Bee-Plane design, manufacturing (or operating) aircraft and detachable fuselages could be completed by separated entities. Marketing of the “detachable fuselage” will be more open to new providers and operators than simply the aircraft manufacturer.

This will address several targets of the challenge 1 “Meeting societal and market needs” of ACARE SRIA, related to aircraft, especially the “*demand for new air vehicles and air vehicle operation concepts* and *acceleration of airport* *operations to support the objectives of traveling in Europe in four hour door-to-door*."

Breakthrough in airport design

Another impact of the concept is in airport design. Currently airports are designed to host a large number of aircraft (with wings) requiring space to load and unload passengers or freight, for maintenance, for refuelling, etc.

The Bee-Plane concept offers a very different organisation as the aircraft operations and passenger/freight operations can be disconnected. The possibility to reduce by a factor of five the size of the airport's terminals provides options for completely different architectures, such as:

- The passenger or cargo terminals could no longer receive the whole aircraft but only a detachable fuselage (without wings) enabling an optimisation of the space required.
- Embarkation and disembarkation constraints are reduced with the aircraft not going to the terminal.
- The aircraft stays directly on or very close to the runway, for loading and unloading operations of the detachable fuselage and for small maintenance operations (de-icing, checking, refuelling, etc.).

Such architecture would allow:

- Increasing the passenger and cargo traffic in existing airports: 2,9 billion passengers in 2013 is projected to become an estimated 6,2 billion by 2032,
- Developing traffic on smaller and new airports with minimal ground infrastructure eliminates the issues of managing existing overloaded airports with projections of 5% passenger increase per year,
- Bringing the passenger closer to other modes of transport (in particular buses, trains, tramways and metro) by using:
  - Closer to city smaller airports with shorter runways,
  - Much smaller passenger terminals disconnected from the overall aircraft logistics constraints thus facilitating intermodal transport.

Bee-Plane allows significant modifications to passenger transportation from the current standard:

- Opening the flight to passengers could be completed in advance, possibly with new embarkation practices (e.g. luggage could be brought directly by the passengers and left in a dedicated compartment like in a train) and, when ready, the fuselage would be brought on the runway for take-off,
- Disembarkation could follow the same scheme and be accelerated allowing passengers to leave the airport directly with their luggage.

This will address several targets of the challenge 1 "Meeting societal and market needs" of ACARE SRIA, related to airports, especially "*Passenger and cargo processes at airports are streamlined and rapid".*

Breakthrough in ground operation

Bee-Plane eliminates the following current operational approaches:

- An aircraft going to a terminal to load and unload passengers,
- An average time of 30 minutes for a typical A320 aircraft to land, unload passengers and luggage, load new passengers and luggage and take-off,
- Additional taxiing time and parking time of about 45 to 60 minutes for a low cost airline,
- A refuelling operation that is on the take-off critical path during ground operations.

The Bee-Plane concept will have an important impact on ground operations. Usage of the Bee-Plane will allow new and much faster ground operations since:

- A Bee-Plane will usually land, unload the fuselage that will go independently to the terminal (with electric propulsion or with the help of an airport vehicle) and immediately load a new fuselage ready for take-off. This second detachable fuselage can be ready for take-off with pre-embarked passengers, before the aircraft actually lands at the airport. Today, passengers have to embark after previous flight passengers have disembarked.
- Time between landing and take-off would then be reduced to 15 minutes as all operations are asynchronous, the time constraint is no longer the loading of passengers but the aircraft itself which requires time to cool the brakes (between a landing and a take-off) or for aircraft checking, etc.
- Fuel needed for the next flight is embarked within the detachable fuselage and then transferred to the engines during flight trough secured fuel connectors that are part of the connexion system. On the detached fuselage, refuelling operation can be done before passenger embarkation. Today, on regular aircraft, refuelling has to be done between landing and take-off.

On main airports, compared to the six flights a day of a current A320 for a frequent flyer airline, a Bee-Plane could add at least two flights per day. On regional airports, where aircraft are spending more time on the ground waiting for passengers the detachable concept will have more benefits. Loosing less time on the ground, pilots and crew flight could also have adapted planning. This will address targets of the challenge 1 “Meeting societal and market needs” of ACARE SRIA, including infrastructure development in line with mobility needs.

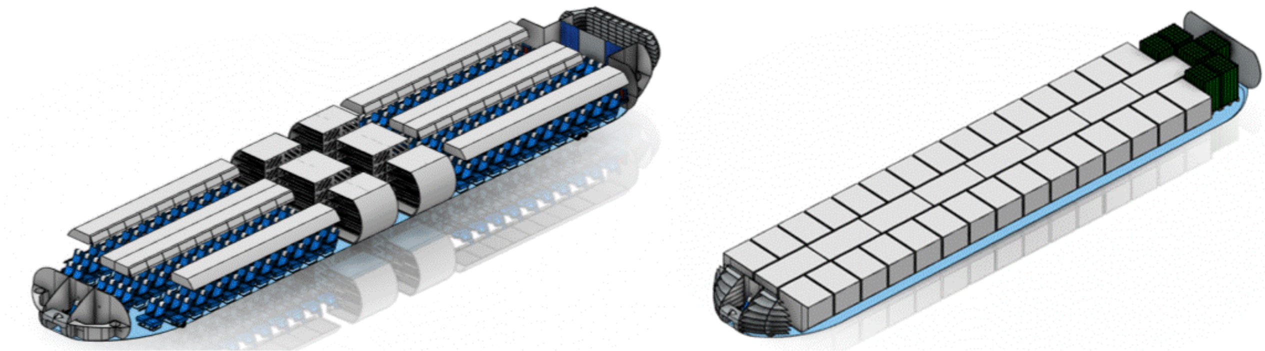

Figure 18: Detachable fuselage for passengers and air freight (Supmeca, 2014)

In addition, this will also provide means for greater flexibility in freight transport, as this is the case with containers used on ships, trains and trucks. Dedicated freight terminals could be set up to transfer goods directly from the fuselage to trucks and trains (with existing LD3 or LD8 lower deck container used generally in air freight transportation).

As for the previous sub-section, this will also address several targets of the challenge 1 “Meeting societal and market needs” of ACARE SRIA, related to airports, especially “*Passenger and cargo processes at airports are streamlined and rapid”.*

BREAKTHROUGH ON COST FOR AIRLINES

The Bee-Plane concept is expected to represent significant reductions in operating and purchasing costs.

TRL1 studies already show between 21% and 28% decrease in airline operating costs for regular intra-European flights (Echabé, 2013), mainly due to fuel burn reduction and flight time optimisation. Additional cost reduction should occur when dedicated low cost airport terminal would be implemented.

On purchasing costs, the price of the detachable fuselage is a key element of the economic studies for airlines. An airline with multiple medium range aircraft (public list price of approximately 71m€ or 95 m$) can replace part of their fleet with a reduced number of Bee-Planes (list price estimated at 70m$) and greater number of detachable fuselages but with significant lower price (estimated at 25m$).

For example in 2014, Air France owns 121 medium aircraft for an estimated public list price of 8,295 m€. Half of the fleet, 60 aircraft for approximately 4,426 m€, could be replaced by 40 Bee-Plane aircraft and 80 detachable fuselages, for an estimated list price of 3,636 m€ enabling a decrease in purchasing cost of approximately 19%. Both for existing aircraft and bee-planes, airlines only pay a reduced percentage of list prices.

Air France fleet	Number of aircraft	Unit price	Purchasing cost (m€)
A319	41	71.5	2932
A320	44	71.1	3130
A321	25	83.4	2085
737-800	11	70.7	778
Total	121		8295
Half of the fleet	60	73.8	4426

Bee-Plane simulation	Number	Unit price	Purchasing cost (m€)
Bee-Plane aircraft	40	53,0	2121
Detachable fuselage	80	18.9	1515
Bee-Planes fleet	40 (+80)		3636

Table 19: Bee-Plane purchasing cost on half of the Air France medium range fleet

TRL 2 studies need to now conduct costs and prices analysis to refine TRL1 economic studies (Ammour, 2014) that are too basic. During the project, detailed structural and equipment design will lead to more precise production cost estimation. The use of standardisation, commonalities and modularisation techniques will also allow streamline and reduce the cost of preventive and curative maintenance and conversions. This will address several targets of the challenge 1 “Meeting societal and market needs” of ACARE SRIA, especially regarding affordable transportation, challenge 2 “Maintaining and extending Industrial leadership “regarding “*Innovative Maintenance Repair and Overhaul*” and of the challenge 3 “Protecting the environment and the energy supply”, especially “*Land-use planning and development”,* and *“SMART Airport cities”.*

2.1.2 Innovation potential

The Bee-Plane is a radical innovation that will:

- Positively affect passengers by decreasing the travel cost,
- Reduce the environmental impact while respecting more sustainability goals,
- Decrease overall costs of the aircraft industry and related business model (airports, airlines, manufacturers).

Technical innovations are described in section 1, the other non-technical and major innovations will be:

- Improvements in **airline’s business models**. A separation between technical operators (aircraft operations) and commercial airlines (detachable fuselage operations) can be done. Business models set up for aircraft owners, detachable fuselage owners and Bee-Plane (as a whole) owners offer much more flexible air transport of passengers and goods,
- A change in the **business model of passenger air transportation and airport ground operations** enabling a step change in overall performance (costs, average travel time, etc.),
- Improvements in **airport design and run** with an 80% reduction of passenger terminal size. Only detached fuselages are parked in front of terminals. Complete aircraft and their wings stay in taxiways. Passenger conveyor belt of existing airports become redundant freeing more space in the terminals,
- A change in the way passengers, luggage, freight and services (galleys, toilets) are organised before and after the flight itself. Reducing the passenger travel cost. **Simplifying the fields operations** will decrease automatically the airport taxes which sometimes are higher than the ticket price for passengers. Reducing passengers’ waiting time and accelerating people flow within the airport terminal. Embarking/disembarking of goods and passengers independently from preparing the aircraft.

2.1.3 Societal and environmental impacts

The Bee-Plane concept will also address environmental and societal aspects with the following impacts:

ENVIRONMENTAL IMPACT

A Bee-Plane has an efficiency goal of 3L/PAX/100km with existing engines. This means that the use of these newly designed and flexible aircraft could help to reduce globally the environmental burden while increasing services to customers and especially with:

- Reduced gas emission on airports by reducing taxiing as the aircraft will not have to go to the terminal and could drop a fuselage and take another one where it has landed,
- Reduced emissions during cruise flight thanks to the use of two of the most advanced and fuel effective turbopropellers (TP400) and take benefit of the additional thrust of the rear turbofan only during take-off or go around manoeuvre,
- These benefits are achieved with existing engine technology with further improvements possible over the 2040/2050 timeframe. Aircraft modular conception allows an easy integration within the fleet of future engines developed. Furthermore, high main wing is an opportunity for open rotor architecture usage.

Again, this will address the targets of the challenge 3 “Protecting the environment and the energy supply” of ACARE SRIA, especially “*Radically new A/C concepts*”, “*Emission free taxiing*” and “*Improved airport access*”.

SOCIETAL IMPACT

Bee-Plane contributes to the overall objective of reducing door-to-door time for transport, especially:

- By developing traffic on regional or closer to the city airports,
- Decreasing delays due to complex and long procedures for embarkation and disembarkation.

Detachable air transportation brings radical cost reduction in commercial models optimising the use of the aircraft and increasing flexibility for the transport of passengers, freight or other applications.

Possibility to develop dedicated applications for specific urgent interventions (flying hospital, water bombers, etc.) addressing population requirements for a fast response.

This will address of the challenge 1 "Meeting societal and market needs" of ACARE SRIA, especially regarding affordable transportation, "*Win-win situation between aviation infrastructure and neighbours*", "*Infrastructure development in line with mobility needs*", "*Optimised airport infrastructure*", "*Innovative services to airspace users*" and several others.

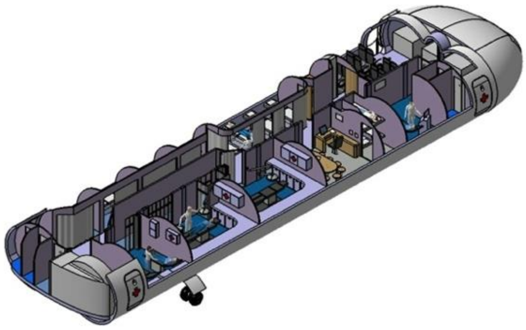

Figure 20: Bee-Plane hospital (Estaca, 2013)

2.1.4 European competitiveness

The need for aircraft in the coming years is drastically high with more than 29,000 new passengers and freight aircraft estimated to come into service from 2013 to 2032. Europe "in-service fleet is forecast to represent 20% of the world's total by 2032." and would have a "traffic increase of 4% in coming 20 years", see (Airbus, 2013). Nevertheless, even if aircraft manufacturers progress in developing bigger aircraft (25% capacity increase in the last 20 years) and in reducing their fuel consumption (mainly with new engines), the sizes of aircraft have limits especially due to ground operations and environmental pressure. Aeronautics is also a key European economic sector (9 million jobs, contribution to 600 billion Euros to Europe's Gross Domestic, 450 airlines and over 700 airports) with an increasing competition coming from newcomers in the market e.g. in China or in Russia. Coupled with the ambitious objectives of Europe in the field for 2050, the introduction of breakthrough innovative concepts is required to address these threats to European competitiveness and societal/market demand.

Thanks to the flexibility offered by separating the load/passenger transportation fuselage from the aircraft, using Bee-Planes will address these needs and have several impacts on the European economy through several new business opportunities:

- Fuselage design opens a very large panel of possibilities: standardisation for low-cost ones or highly specific (VIP fuselage for instance). The aircraft will be kept evolving according to a different product life cycle (new generation of turbines, computers, etc.). Both together, they offer a huge air industry market and big chance of highly qualified operators, technicians and engineers in the European territory,
- Different types of operations and multiple opportunities are offered for aircraft operators and detachable fuselage operators. New businesses are opened to the air industry supply chain actors and SMEs operating on specific tasks on standard or customised fuselage,
- Development of regional connections all around Europe exploiting the flexibility of this transport mode and the typical commercial flying range of 700km to 2000km looked at by Bee-Planes, releases the largest airports from the overloaded issues they currently experiencing and which will worsen by 2050. As a side benefit, this could also have a positive impact on air quality and environment by reducing the number of transit flights,
- Lower cost flights, increased flexibility of regional flights (with fuselages including a mix of passengers and fret) and agile flight scheduling all lead to significant consumer benefits for European citizens.

As part of the impact on European competiveness, important aspects of the project are to:

- Implement a concept-plane project with a European consortium of academia, industrial and SMEs that will drive innovation in aeronautical field,
- Explore how to exploit Bee-Plane developments on more traditional aircraft to be able to stay at the leading edge of the aircraft industry,
- Develop methodologies and partnerships within existing European aeronautical industry focussed on "out of the box" projects in order to continuously challenge R&D departments and research institutes.

2.1.5 External factors influencing the projected impact

Several factors can negatively impact the growth of the Bee-Plane concept, the project dissemination and exploitation as described in the next section are focused on these factors to minimise the risks and prepare the ground for further developments:

- The aircraft industry is highly competitive and requires important investments: the two market leaders will together have 87% of the market share between 2013 and 2032 according to Ascend (Ascend 2013). This

means that the only possibility Bee-Plane has to make this concept successful is to be able to convince the main market leaders of the concept's suitability and benefits. Without involvement of an existing company, helped by public and European authorities, market uptake will be difficult to achieve.
Mitigation strategy of the project: Efforts will be deployed to attract the interest of the aeronautical industry by focussing on impacts studies. Rapid progress will be achieved with resources efforts that European funding could bring. Dissemination tasks, at the end of the project, based on solid technical and economic results act as a powerful mitigation strategy. Today's consensus is that project is still at too early stage for large industrial partners or airlines to be involved in. As a comparison, a new molecule is developed by R&D firms and then is transferred to the pharmaceutical industry.

- Other stakeholders of the air transport industry must also be involved and convinced. They could contribute to the success according to their profile, market position and potential business: airlines (potential customers who need to develop their own business model), airports (on the ground operators who need to transform their infrastructure) and first tier suppliers (major aircraft or equipment manufacturers that could in a first stage be interested by by-products).
Mitigation strategy of the project: The involvement of the main actors from the beginning of the project in two Specific Interest Groups (Airports and Airlines) can ensure the right direction of the research and development of the project from one side and a step ahead towards the market.
- Financing a new aircraft is also a key challenge as building a new aircraft requires several billion euros for the design, development, certification, manufacturing plants and commercialisation including developing business plans supported by future clients (aircraft programmes are now started only after the commitment of the first clients to purchase the future aircraft) to get support from investors.
Mitigation strategy of the project: the project involves a rapidly growing consortium of universities, technical offices, SME and industrials. As project will develop, future partnership will be implemented according to project needs. Existing players within the aeronautical network (industry, airlines and capital firms) are able to fund a complete aircraft program (as Bee-Plane). Nevertheless return on investments is usually considered on 10 to 20 years periods. At early stage of the project development (TRL2/TRL3/TRL4), European funding could accelerate timeframe and lead to greater technical, economic and social benefits.
- Certification of such an aircraft could be difficult as currently certification authorities do not have any reference for such a novel aircraft design.
Mitigation strategy of the project: Today, there is minimal aircraft prototyping and a reduced number of test flights. Once designed, an aircraft is manufacturable and respects all the necessary requirements for certification. Relying on these facts, Bee-Plane will use the same approach as of aircraft manufacturers. To be certified and in compliance with existing manuals (Aircraft Maintenance Manuel, Engine Maintenance Manuel), Bee-Plane will need a dedicated maintenance manual for the detachable fuselage (Andreeff, 2014). Contact with certification authorities (EASA to start with) will also be established to outline specific issues of Bee-Plane certification.
- Acceptance of the passengers will finally need to be supported as flying in a detachable fuselage might create some reluctance and fear.

Mitigation strategy of the project: Fuselage is only detachable during ground operation; it is not detachable in flight. Forces within the locking system are already estimated to fulfil all maximal constrains. Project will provide reliable design, impact studies and economic benefit that will be communicated through dissemination events to increase public engagement and acceptance of the design.

2.2 Measures to maximise impact

Due to the nature of the aircraft industry the development of such a highly novel design as the Bee-Plane is a long term project targeted towards operational flights in 2040/2050. It is therefore vital that the impacts of the project for traditional and incremental aircraft designs are identified, matured and disseminated over the project lifetime. The strategy of the Bee-Plane collaborative project is to achieve open innovation within a consortium that will be expanded to include additional stakeholders after each significant step. Information and project documentation are shared between the participants and with potential future partners. Most documents will be public according to the lesser open source agreement. The future partnership will be progressively extended from the existing consortium including:

- Technical partners: contacts have already been established with several aeronautical industrial and research organisations which have already led to support or interest to explore collaborations when TRL 2 will be achieved. To start with, the strategy is to focus on aeronautical feasibility. It will allow the establishment of a starting point for future research in logistic, economic and organisational schemes. The key milestone will be to initiate the TRL 3 studies addressing not only the technical aspects but also the first industrialisation issues.

- Certification authorities: dedicated documentation and certification will have to be shared and implemented to take into account project's technical specificities. The project will approach EASA for that purpose.
- Stakeholders: first contacts have been taken with some airlines and airports and by the end of the project contacts will be developed with several airlines and with airports. Specific Special Interest Groups will be set up inside the project for that purpose and supporting documents will be used to develop an argument matching these stakeholders' requirements: costs, operations, traveller satisfaction, etc. The initial purpose will be to get encouragement and support to convince potential technical and industrial partners to develop a technical relationship. A second important purpose will be to refine the marketing concept to identify first customers.
- Finances: a preliminary development plan and business plan will be prepared split in several phases concluded by major milestones and covered by a preliminary budget including assumptions on where it could come from.

In addition, to make the impact concrete, **impact indicators** will be developed to assess the different impacts mentioned in section 2.1. These indicators will be detailed as part of the project dissemination and exploitation and used for exchanges with potential partners for the next phases and with stakeholders (airports, airlines, etc.):

- Cost aspects on transporting passengers and freight with detachable fuselages vs. standard aircraft. The cost indicators will take into account acquisition, operations, maintenance and depreciation costs against potential revenues according to different scenarios (e.g. average number of passengers, low cost vs. standard airline, usage of different fuselages, etc.),
- Cost of operating a Bee-Plane versus a traditional aircraft. The previous cost indicators will be used to compare Bee-Plane to existing aircraft and foreseen evolutions of traditional aircraft in the next 20 to 30 years,
- Acceleration of operations: fixed wing vs. Bee-Plane. The indicators will concentrate on operation time including time between take-off and landing, time between embarkation and disembarkation,
- Airport capacities: number of passengers per day, size, cost, etc. The indicators will be used to compare at airport level the difference between traditional aircraft and Bee-Plane in order to assess the potential benefits and simplifications of processes in a traditional airport as well as in a Bee-Plane dedicated airport.

These indicators will be compiled to provide an overall picture showing significant economic and time gains compared to traditional aircraft and confirm the project objectives of reduction by a factor of 5 in the airport terminal's size, of up to 30% on ticket price and of the fuel burn below 3L/PAX/100km.

The following sections detail these actions at consortium and individual levels.

2.2.1 Dissemination and exploitation of results

The first Bee-Plane objective in terms of dissemination and exploitation is to prepare the ground to move the technology to a higher maturity level. This will be achieved by implementing measures targeting the innovation dimension of the project, essentially IPR management, preparation of a development and exploitation plan, setting up and monitoring of side projects and developing a network of contacts with all stakeholders.

The second Bee-Plane objective is to ensure that the potential impact of the project receives the visibility needed to attract new partners for the next steps of development:

- New scientific partners to conceptualize, publish and disseminate all scientific and technical aspects to the research community,
- New Industrial partners to support the development of the key technologies needed at TRL 3 and 4, possibly analysing long term industrialisation and market aspects,
- Airlines and airports, to provide operational and marketing information for developing Bee-Plane business plans,
- The public to gain visibility for potential partners, then ensure acceptance of the technology, potential support for new developments.

This will require a series of measures targeting all stakeholders to discuss potential solutions and to convince them to consider the technology developed in Bee-Plane for future development and usage. This objective will be achieved by detailing impact indicators and implementing dissemination and communication measures directed at and with those stakeholders (see below section 2.3.2).

A special task in WP7 will take care of dissemination to better spread the project's results. This task will set up a dissemination action plan in order to communicate efficiently with project partners and the scientific and business community. The proposed work includes:

- Use www.bee-plane.com public website to allow public access to web-pages which will report project progress,
- Disseminate results through papers in appropriate journals, at conferences and on company and EC web sites including impact indicators,
- Develop communication material (flyers, posters, brochures),
- Develop Bee-Plane popularisation videos posting on the most useful sites,
- Set up and deliver courses and training plus engineering projects to be done outside the Bee-Plane project but contributing to strengthen TRL 2 achievement and initiate TRL3 studies,
- Prepare a final public booklet presenting the project achievements and perspectives targeting potential partners for next steps,
- Organise a public workshop to be held close to the end to provide an overview of all project results and in particular ways forward.

2.2.2 Management of knowledge and data

In order to assure the success of Bee-Plane, all project partners before the start of the project have agreed on specific rules with regards to Intellectual Property (IP) ownership, access rights to any Background and Foreground IP for the execution of the project, the protection of intellectual property rights (IPRs) and confidential information. For this purpose a Consortium Agreement (CA) will be agreed upon and signed by all project partners. The Bee-Plane CA will outline the legal framework for the above mentioned issues, with the purpose of minimising related conflicts during the project.

KNOWLEDGE PORTFOLIO MANAGEMENT AND KNOWLEDGE PROTECTION

The first main Bee-Plane dissemination objectives are to prepare the ground to move the technology to a higher maturity level. In practice, the following strategy will be followed inside the project:

- **Prepare a development and** exploitation **plan** to further mature the technology through new projects (industry supported projects, national projects or potentially HORIZON 2020 projects) with the current partners but also targeting larger partners from the industry or large European research institutes in the field. As an output from the project, the key developments requiring research work will be identified. The plan will include a preliminary specification of these projects mostly targeting proof-of-concept through analytical and experimental investigation of critical functions (TRL 3). Estimation of budgets and the required academic and industrials expertise will be established. This plan will also include as an annex a public booklet presenting the project achievements and perspectives to be used for communication purpose, including an analysis of the potential economic and organisational benefits for airlines and airports. The existing and future business plans of **TECH** (made outside the project) will also serve as input for this development and exploitation plan.
- **Implement and monitor in parallel** side **projects** with engineering schools to strengthen the technical aspects of the project. The Bee-Plane concept has and will continue to be investigated through Masters level research projects in several engineering programme. For the research and university partners the topics under study will be developed in their engineering programs:

  For **MGEP**, the research topics covered in the project will be further developed in Masters Research projects with a minimum of 30 ECTS included within the University of Mondragon Industrial Engineering Master Study Programme. The results will be published in research academic presentations and conference and journal articles.

  For **TCD**, the Bee-Plane concept has and will continue to be investigated through Masters level research projects in the TCD engineering programme. These research projects are significant 35 ECTS projects with the expectation that the results will be suitable for publication in conference and journal articles.

  For **ISMEP**, the projects resulting of the Bee-Plane concept will also be conducted within mechanical and logistic departments of ISMEP (9 ECTS projects where the main issue is to practice methods and technologies for system engineering, especially: (i) Materials, process and simulation, (ii) Production systems and logistics, (iii) Modelling in mechanical engineering, (iv) Mechatronics and complex systems, and (v) Simulation for mechanical design. These projects are conducted by researchers of ISMEP and results are subject for publication in international and national conferences and journals.

For **UNINA**, the project will serve as a base line for further aerodynamic studies and related courses using UNINA wind tunnel. Also UNINA will finance contracts for fixed-term researcher, PhD or Temporary Research associate having as its object the study of Bee-Plane

- **Organise a** proper **management** of **the IPR** to ensure that results are protected, ownership is clearly defined and access rights to background and foreground are properly specified and accepted by all partners. The strategy is to stick to the rules of the DESCA consortium model and to monitor the process through a Bee-Plane Knowledge register used to collect information on the generated foreground including protection to be made and access rights in order not to create showstoppers or issues in exploitation. Overall Bee-Plane project and other contributions are managed with Lesser Open Bee License. It is a project license written specifically for the Bee-Plane project that allows collaborative work and open innovation (see http://www.bee-license.com for details). Such a license is useful in guaranteeing an easy access to potential new partners. It facilitates the preparation of future TRL 3 projects while protecting the owners of the project foreground. Tasks that will be achieved during TRL 2 by the consortium will mainly be included within Paragraph 2 "Open Bee Preamble" of the Lesser Open Bee License Revision 1-3. It means that publication will mainly be achieved through public technical wiki of the Bee-Plane project. Information System Tools brought in the project by partners (especially simulation tools by LMS-SAM, and also regular existing IT tools) are included in Paragraph 5 "Associated work" and keep their own license. Publications will be validated by the Governing Board to avoid potential protection issues. **ARTTIC** will finally play a role of moderator in case of difficulties and conflicts on IPRs.

DISSEMINATION, INCLUDING PUBLICATIONS

The second Bee-Plane dissemination objective is to ensure that the potential impact of the project will be achieved at academic, industrial and societal levels. Dissemination will take place again with the primary objective of preparing the next developments steps. The activities listed below are expected to be funded only partially by the project, as the scope is much wider than what could be done with the project dissemination budget.

The main targets for dissemination will be:

- Large industrial organisations that could support the development of the next steps. Initial contacts have already been taken (among them, Airbus/ Airbus Group Innovations provided a letter of interest) as the detachable fuselage concept (or POD in this case) is also a potential solution advocated for the future by e.g. Airbus (see (Airbus, 2011)),
- Potential "customers" who could help in refining the concept to improve our understanding of their expectations for the future and present Bee-Plane as an alternative concept to more traditional solutions: airport engineering companies (e.g. Aéroport de Paris Ingénierie) and airlines (e.g. Air France or Easy jet),
- Large academic institutions that also have ambitious projects for 2050 – in particular contacts have been taken with EPFL to exchange information related to the Bee-Plane and Clip-Air projects,
- Engineering schools that could support the project: several are already collaborating with TECH in France (Ecole Centrale Paris, ESTACA, IFMA, INSA, etc.) as well as TCD, ISMEP and UNINA,
- Dissemination to the general public will be targeted to make people aware of alternative transport solutions that could better correspond to the requirement of cheaper and more efficient air transport.

2.2.3 Communication activities

The means to reach the target audiences will be through:

- Direct contacts with key industrial and research organisations exploiting the network of contact of the partners, notably ARTTIC and TECH, the setting up of two Special Interest Groups (SIG) one for airports (Lyon, Clermont-Ferrand, Bordeaux-Merignac and Bergerac in France and Birmingham already agreed to be involved, contacts on-going with others) and one for airlines (contacts on-going with different airlines) will also be a key vehicle to develop these contacts.
- Publications in aeronautics conferences and journals (e.g. Air & Cosmos, Aviation week, Flightglobal) as well as economic or general newspapers and journals which is already the communication strategy of TECH.

- Participation at aeronautics events like Le Bourget Air show (in 2015 and 2017), Farnborough or Berlin ILA Airshows the EC Aerodays, etc., whenever possible on the booth of supporting organisations like Normandy AeroEspace (NAE).
- Participation to scientific conferences like the annual AIAA/CEAS conference (premier venue for aero acoustics research in Europe), or the Normandy AeroEspace RTI Days (exhaustive list given below in figure 22.
- The public website www.bee-plane.com is constantly updated to promote the main benefits from Bee-Plane in terms of the impacts for the airports, airlines and passengers and in terms of scientific, technical and industrial achievements. The impact indicators of section 2.2 will in particular be published and promoted on the web site.
- Public technical wiki of Bee-Plane project (website on technical documentation based on Wikipedia architecture), accessible from technology section of www.bee-plane.com. As for TRL1, this website will be used to disseminate public documents and publications and to promote exchanges on impacts, possibly through the impact indicators. It will present the next steps following the project and collect feedback.
- Participation to scientific events targeting European citizens such as the “Fête des Sciences” in France with the support of the academic partners of Bee-Plane.
- Finally, social networks will also be used to disseminate regular short updates on the project, starting with the already heavily used @Bee-Plane twitter account. An electronic newsletter will also be published to give more extensive description of the project achievements and related information.

Project will also take benefit of Partners competences. Bee-Plane will be widely disseminating the knowledge created by the project with the aim to promote adoption of:

Target	Dissemination channels
Aeronautical community	Twitter account @Bee-Plane, that is followed by aeronautical players
Airbus & other airframers	Workgroup and focussed communication
Airports and airlines	Direct contact through Special Interest Group
Certification institution	Communication for future project on certifications and standards

Event	Typical participants	Interest as dissemination channel
AIAA/CEAS conference	Premier conference for aero-acoustic research	TCD has a regular presence at the conference each year, Most recently for the Clean Sky projects WENEMOR and ALLEGRA
Ecole Centrale Paris Alumni (Aeronautic group)	Main aeronautical player in France and Europe	Prepare communication to future partners
Normandy AeroEspace RTI Days	Aeronautical Industries in Normandy	Communicate with aeronautical industrials
Nafems	Technical offices	Main conference about FE Analysis
ICED International Consortium for Educational Development	Academia	Involve other academia in Bee-Plane project
APMS Advances in Production Management Systems	Industrials and logistic organizations	Communicate and assess models used to establish project performance
IFAC-MCPL International Conference on Management and Control of Production and Logistics	Industrials and logistic organizations	Communicate and assess models used to establish project performance
Worldwide Air Transport Conference	Aeronautical players	Involve other organizations for future steps of the projects
International Conference on Research in Air Transportation	Research institutes	Involve other organizations for future steps of the projects

Journal / Publication	Typical readers	Interest as dissemination channel
AIAA Journal (world leading journal for aero-acoustic problems)	Technical office and industrials	TCD could publish the results of the propeller, jet and landing gear noise

		problems here
Applied Acoustics	Industrials and technical offices	Innovative codes of source models could be detailed in publications here
Journal of Sound and vibration	Industrials and technical offices	The transmission and interior noise problems could be published here
Air & Cosmos, Aviation week, Aerospace Science and Technology, Flightglobal	Aeronautical players, general public	Aeronautical weekly publication that have broad readers range
Usine nouvelle	Industrial players	Overall communication to industrials
Journal of Computational and Nonlinear Dynamics, International Journal for Numerical Methods in Engineering	Research institutes and R&D departments of industrials	Involved R&D communities
Journal of engineering design	Research centres and R&D departments of industries	Progresses beyond the state-of-the-art about change modelling and propagations
Intelligent manufacturing systems, International Journal of Logistics Management	Research centres and R&D departments of industries	Modelling and evaluation of scenarios for airports' supply chain
Technovation	Research centres and R&D departments of industries	Progresses beyond the state-of-the-art about change modelling and propagations
Journal of Air Transport Management	Research centres and R&D departments of air industry companies	Definition of Airplane-Airport-Environment analysis with related processes and operations
Composite Science and Technology	Research centres and R&D departments of industries	Advances on multimaterial joining systems

Figure 21: Bee-Plane communication activities

3 Implementation

3.1 Work plan — Work packages, deliverables and milestones

3.1.1 Overall structure of the work plan

The preliminary work plan is made of five technical work packages and three supplementary work packages for the analysis of ground operations, the dissemination and exploitation and the management of the project.

A systematic view of the main activities to be carried out during the project can be found on the figure below:

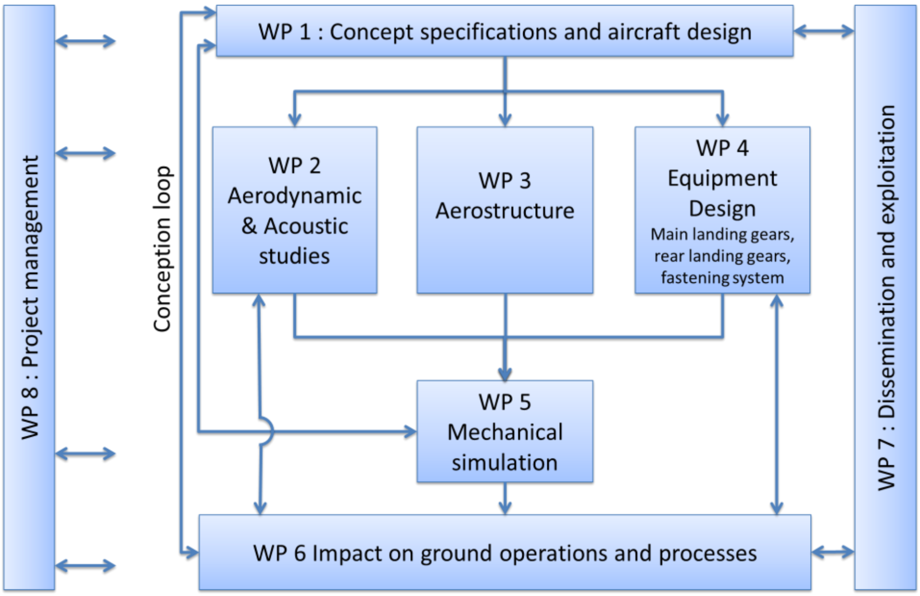

Figure 22: Work breakdown structure

The project will be conducted in three years and organised in three phases:

- First phase (over one year) to confirm aircraft configuration, publish updated analysis and results,
- Second phase (also over one year) to complete TRL 2, establish detailed reports and advanced numerical analysis,
- Third phase (during the last year) to focus on showstoppers, start critical TRL 3 items and finalise detailed studies.

Critical Design Review will be conducted at the end of each intermediate year (month 12 and month 24) and at the end of the project (month 36).

WP1 - Concept specification and aircraft design (resp. TECH)

WP1 is leading the conception loop to establish a complete TRL2 configuration of a medium range aircraft with detachable fuselage. WP1 will assess work done in order to establish optimal aircraft configuration (especially weight) and airport models (logistic benefits). WP1 will develop the Bee-Plane detachable concept according to the results of other work packages. Methodologies used will compare performance to regular medium range aircraft. Critical items of TRL3 are started and a larger consortium is involved according to impacts and exploitation plan. A final assessment will be published to guide next steps from a technical and innovation point of view (including technologies that can be transferred to traditional aircraft).

WP2 - Aerodynamic and acoustic studies (resp. TCD)

WP2 will perform the aerodynamic and acoustic studies needed to assess the aircraft design. WP2 is a key element of the conception loop. Results of design tasks of other work packages are integrated in WP2 studies that will identify key areas where further changes are needed. WP2 will assess major innovations developed within the Bee-Plane project such as the triple bubble fuselage, tail dragger configuration and mix of engine's types. Impacts of main equipment design will be critical in WP2 studies as length of landing gear and conception of the tail. WP2 will quantify the results on the final design to prepare next studies at TRL3.

WP3 - Aerostructure (resp. AED)

WP3 will focus on the structure of the aircraft and its detachable fuselage. A conceptual design will be conducted during the first year and will provide data for mechanical simulation (WP5) and aircraft studies (WP2). A detailed design will then be established to take into account intermediate results of studies (WP2, WP5) and aircraft changes (WP1, WP4). Aero structure is critical to establish project TRL2 due to the enormous impact of weight assessment on airlines operational costs (mainly due to related fuel consumption). Linked with aircraft design (WP1), equipment design (WP4) and impact studies (WP6), WP3 will show if additional structures needed for the structural integration of the detachable concept are balanced with other gains (as triple bubble fuselage) and overall economic impacts (logistic gains, fuel consumption reduction, etc.).

WP4 – Equipment design (resp. UNINA)

WP4 will focus on the design of Bee-Plane main equipment including fastening system, main and rear landing gears. The main equipment has been identified as potential showstoppers of the project during the TRL1 studies. This dedicated WP4 is focusing on those critical elements to quickly reduce project risks by designing adapted mechanism. Detailed equipment design will be an input of structural design tasks (WP3), aerodynamic and noise studies (WP2), kinematic issues and materials choice. Functional analysis will take into account specific technologies used in Bee-Plane such as lowering the aircraft to drop detachable fuselage and having a tail dragger configuration. Malfunctioning of any equipment will also be taken into account in mechanical simulation work package (WP5). TRL2 final equipment's configuration (WP1) will be used to identify future industrial partners to be included in project future phases (WP7).

WP5 - Mechanical simulation (resp. LMS-SAM)

WP5 will study, through simulation (which means simulating the real plane as an equivalent model on computer), the behaviour of Bee-Plane at different steps or situations (landing, fuselage connection and disconnection, non-opening of landing gear). Typically, stresses, strains, eigenvalues (dynamic behaviour, critical dynamic values, etc.), dynamic response (dynamic behaviour induced by motors vibrations, landing impact, etc.), temperature field, etc. will be evaluated. Mechanical simulation will provide coherency to the technical project. WP5 is the final step of the conception loop. Aircraft design and studies (WP2 & WP3) and equipment design tasks (WP4) provide inputs (as the dimensions and shape of designed structure) and will take account of returned outputs of simulation. Standard computation methods (as linear or non linear elasticity of a structure, dynamic behaviour theory and thermal effect theory) are used to assess materials constraint and overall concept feasibility. WP5 focuses on main scenarios where mechanical constrain is maximal. It will identify critical TRL3 items to be analysed during last of design (WP1, WP3 and WP4) and studies (WP2) and presented to future project partners (WP7).

WP6 - Impact on ground operations and processes (resp. ISMEP)

WP6 will assess the potential impacts of Bee-Plane concept on airports, their supplier's network, and airlines, all together intertwined within the global environment. It will include the definition of processes of ground operations and their management as well as the possibility to design new types of airports, smaller, cheaper and closer to the passengers. Impact studies are critical for project next steps (WP7). Targeted results (fuel burn, ticket price reduction, etc.) will be confirmed. Acquisition and operation costs for airlines will be estimated and will provide necessary information to refine concept definition (WP1) and convince airlines and airports involved in the Special Interest Group to join project for TRL3 and TRL4.

WP7 - Dissemination and exploitation (resp. ARTTIC)

WP7 will prepare the next steps after the end of the project (how to move the technology forward, preliminary business plans and extension of the partnership) and support the dissemination of the project achievements through publications and participation in workshops. Bee-Plane Special Interest Groups will involve aeronautical players (airlines, airports, manufacturers, research centres) and will identify potential future partners where a dedicated communication is needed.

WP8- Project management (resp. TECH)

WP8 will provide the project management infrastructure to ensure the efficient coordination of the project and to fulfil all contractual obligations.

3.1.2 Work plan timing

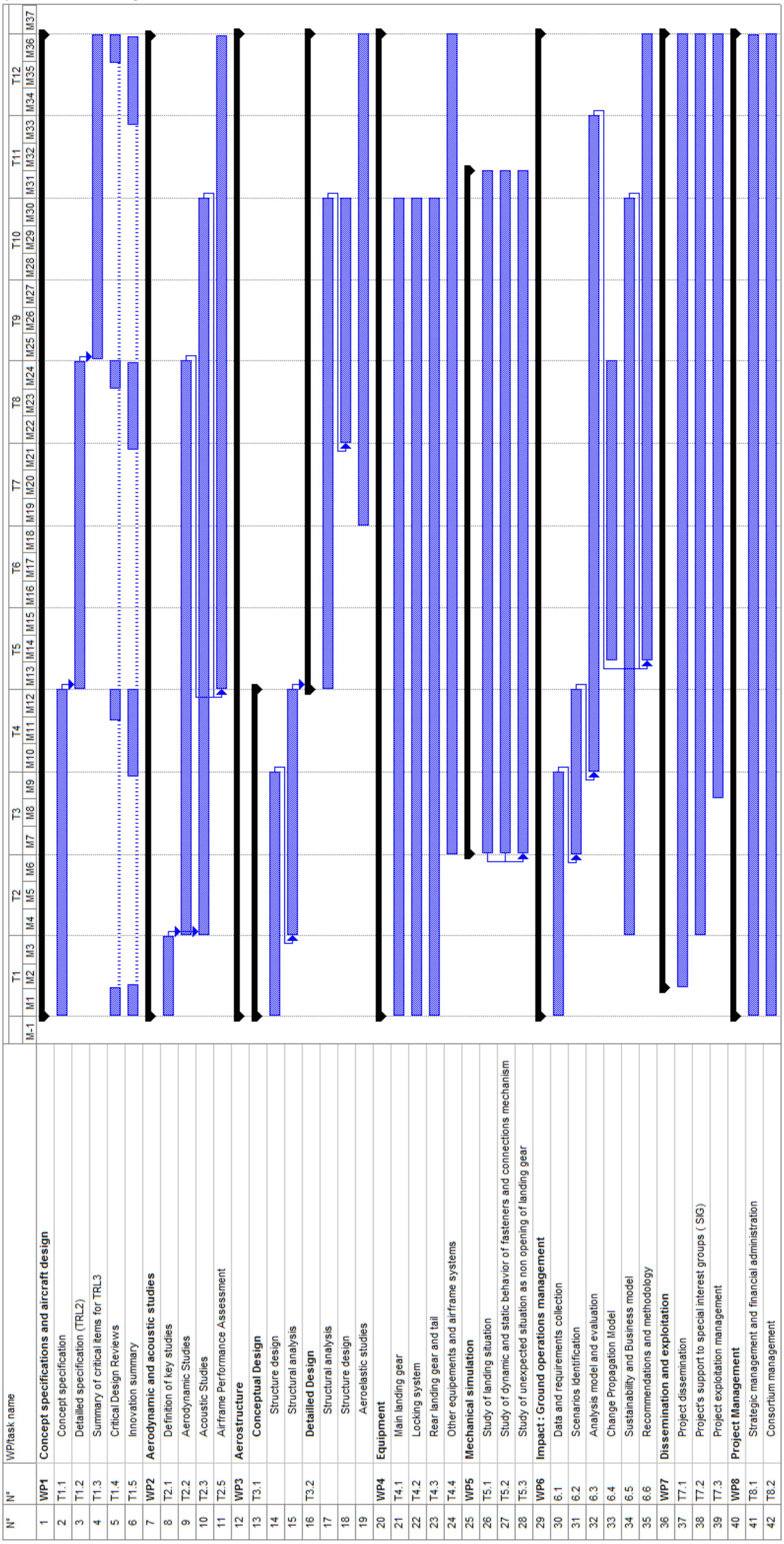

Figure 23 Gantt diagram

3.1.3 Detailed work descriptions: Tables 3.1a

WP1

Work package number	**1**	Start date or starting event:			M1-M36				
Work package title	**Concept specification and aircraft design**								
Participant number	**1**	2	3	4	5	6	7	8	9
Participant short name	**TECH**	ERT	LMS-SAM	TCD	ARTTIC	UNINA	MGEP	AED	ISMEP
P.M. per participant	**32**	0,5	0,5	0,5	0	0,5	0,5	0,5	0,5

Objectives

The objectives of WP1 are to:

- Provide detailed specification of a medium range aircraft with one detachable fuselage: focusing especially on reduction of weight, optimal passenger capacity and estimation of fuel consumption,
- Achieve project technical coordination by providing inputs to other work packages and initiate the conception loop between technical work packages (WP2, WP3, WP4 and WP5),
- Define passenger scenarios and coordinate impact studies on airports and airlines (WP6) with other work packages,
- Update scenarios and concepts, according to results achieved by other partners, and conduct annual Critical Design Reviews,
- Focus on aeronautical innovations that can be implemented in regular aircraft,
- Formalize the methodologies developed to compare the Bee-Plane project with standard aircraft.

Description of work

WP1 will develop the Bee-Plane concept according to results achieved during the project (technical and impact studies). WP1 is leading the conception loop to establish a complete TRL2 configuration. At first, a full economy passenger scenario will mostly be considered to define a basic Bee-Plane configuration, then, this will be extended to other configurations (two classes, multi classes, VIP, fret, hospital, etc.).

During the first year, potential showstoppers identified in previous TRL1 studies will be detailed through economic and technical assessments. During the second year, detailed specifications will be established according to first year results, providing refined inputs for the impacts analysis. TRL2 level will be achieved in month M24 when a detailed design of the complete aircraft, detachable fuselage and main equipment will have been processed through a detailed mechanical, aeronautical and acoustic analysis. TRL2 studies will provide aircraft detailed parameters, related passenger capacity and aircraft fuel consumption. The economic impact compared to standard aircraft is estimated and compared to existing fixed wing aircraft.

In third year, critical items of TRL3 will be initiated. Final project synthesis will be established. A larger number of SIG's participant will be involved according to impacts studies (WP6) and exploitation plan (WP7).

Bee-Plane is also a concept-plane that drives aeronautical innovations. WP1 will regularly assess work done in order to establish the methodologies used and to identify technologies that could be transferred to regular aircraft. A final assessment will be published to guide the next steps from a technical and innovation point of view.

Task 1.1 Concept specification (M1 – M12)

Lead: TECH - Contributors: ERT, AED

Task 1.1 focuses on vehicle specification and concept description. Task will start with project quick-off meeting. TECH will provide updated TRL1 documentation and will prepare initial specifications for project first year. Other partners will provide their input needs and comments on initial Bee-Plane configuration. Then task 1.1 will contain the following activities:

- Provide updated technical specifications (choice of engine, wings size, fuselage diameters and structural constraints, etc.) according to design phases and studies achieved in other work packages (WP2, WP3, WP4 and WP5),
- Provide main dimensions of Bee-Plane and its detachable fuselage (including full economy passenger cabin layout) refining TRL1 figures (100 tons with 220 PAX in single economy class),
- Provide specifications for main equipment (landing gears, APU) and estimate additional weight of the fastening system (WP4),

- Provide detailed list of equipment used in electric, hydraulic and fuel system for upper aircraft and detachable fuselage,
- Provide passenger scenario with optimal PAX capacity and distance range, and establish input data for impact studies (WP6).

Figure 24: Bee-Plane detachable fuselage on an airport (ESTACA, 2013)

Studies will continue technical items opened during the TRL1 studies, including:

- Impact of the central turbofan shut down during cruise flight (estimated increase of 12% of the flying range),
- Estimation of flight parameters during first flight phases (take-off, acceleration, climb and cruise) and impact of an engine failure for each phases,
- Definition of exact weight balance of the aircraft and possible loading cases of the detachable fuselage. Definition of related fuel tank capacities, including additional fuel tank in the rear upper fuselage for easy modification of gravity centre,
- Prepare scenarios of unexpected main equipment failures, as non-opening of landing gears (see mechanical studies in WP5). Define aircraft capacity to land when:
  - One detachable fuselage is loaded and no rear directional landing gears are opened (vertical rear tails touch the ground without wheels),
  - One detachable fuselage is loaded and only one rear directional landing gear is opened (rear tail elasticity will be studied to resist to asymmetric constrains),
  - One detachable fuselage is loaded and no main landing gears are opened (landing on wheels of the detachable fuselage will be considered, as well as landing directly on the bottom of the detachable fuselage),
  - One detachable fuselage is loaded and only one main landing gear is opened (retraction of the functional main landing gear will be considered to be able to land on wheels of the detachable fuselage or directly on the bottom of the detachable fuselage),
  - No detachable fuselage is loaded and no main landing gears are opened: worst case for the upper aircraft, due to propellers touching the ground quickly, but with little impact as there is no detachable fuselage loaded (no passengers). Structure of the nose of the upper aircraft will take into account this crash case,
  - No detachable fuselage is loaded and only one main landing gear is opened. Studies will confirm ability to land in this configuration. Position of gravity centre linked with asymmetric flaps position during landing has to be refined.
- Establish overall economic interest of replacing the two large turbopropellers TP400 (military new engine with 11 000 SHP that have been installed in military fret aircraft Airbus A400m) by four low cost engines Pratt & Whitney PW150A (5 000 SHP); formalize benefits for emerging countries and airlines that are already operating short range aircraft Bombardier Q400 (with two Pratt & Whitney PW150A). Formalize impact on acquisition cost and maintenance cost for such a configuration. Identify if the central turbofan is still needed with a quadri turbopropellers configuration.

Roles

- TECH will lead and conduct the majority of the definition work while other partners will provide their entrance needs and comments on Bee-Plane TRL1 configuration.
- Close relations are established with design tasks: structure (AED) and main equipment (ERT).

Task 1.2 Detailed specification for TRL2 (M13 – M24)

Lead: TECH - Contributors: LMS-SAM, TCD, UNINA, AED, ISMEP

Advanced TRL2 specification of a medium range aircraft with detachable fuselage will be formalized according to the year 1 and year 2 studies. The task will assess the overall feasibility of the Bee-Plane concept and validate the TRL2 phase. The aircraft will be precisely described and updated according to results of studies (technical and impact) made by all partners.

Main target is to establish key parameters of the aircraft, as:

- Optimal weight of the aircraft and related detailed passenger capacity: Studies will confirm exact fuel consumption, fuel capacities (in the aircraft and in the detachable fuselage) and optimal structures weight. Those results will be integrated in aircraft design and capacity of the detachable fuselage will then be adjusted.
- Length of the detachable fuselage: Width of detachable fuselage is already a fixed parameter, but length is the parameter that can be easily modified to increase or decrease passenger's capacity. If a row of seats is suppressed or added, the total length varies by 0.9 meters and an estimated weight of 1.88 tons.
- Estimated price of standard detachable fuselage in full economy configuration. This price is one of the main parameters in the economic model of detachable air transportation. Return on investment for airline and aircraft manufacturer is directly linked with the difference between a standard medium range aircraft and the price of a single detachable fuselage.

TRL2 of the project will finish at month M24. Second Critical Design Review is the project gateway that will close Task 1.2 and Bee-Plane TRL2.

Roles

- TECH will lead technical specification of the aircraft and detachable fuselage, in regard of results achieved in other work packages.
- Design tasks provide numerical mock-up: structure (AED in WP3) and main equipment (UNINA in WP4).
- First studies are integrated in WP1, as: acoustic studies (TCD in WP2), aerodynamic results (UNINA in WP2) and mechanical simulation (LMS-SAM in WP5).
- Impact studies identify key usage scenarios (ISMEP in WP6) that should impact detachable fuselage capacity.

Task 1.3 Final specification and summary of critical TRL3 items (M25 – M36)

Lead: TECH - Contributors: ERT, LMS-SAM, TCD, UNINA, MGEP, AED, ISMEP

After three years of studies, the final specifications will be prepared to cover the exact definition of the aircraft, equipment, mechanism and related studies (aerodynamic, mechanical, acoustic, etc.). Key parameters of the aircraft will be defined at their optimum in regards of all project constrains. It will also provide a synthesis of studied business models and Bee-Plane impact studies (e.g.: decrease of the average travel time across Europe). Main items to be studied at further TRL3 level will be presented (including: technical, process, supply chain, impacts and project potential showstoppers for TRL3). Key market and operational indicators will be introduced and used during dissemination phases. Other detachable fuselage configuration will be listed and assessed (as: hospital, quick emergency forces, etc.).

Taking into account last year of results, task 1.3 is preparing project for future steps of research and developments (not included in this proposal).

Roles

- TECH will provide the final Bee-Plane specifications and assess the corresponding TRL2 feasibility of a medium range aircraft with detachable fuselage.
- All partners will provide results of their year 2 studies and analysis of the aircraft configuration.

Task 1.4 Critical Design Reviews (M12 / M24 / M36)

Lead: TECH- Contributors: ERT, LMS-SAM, TCD, UNINA, MGEP, AED, ISMEP

Critical Design reviews are regular meeting with partners in order to verify maturity of the aircraft design. CDRs determine that technical effort is on track to complete project objectives (according to targeted results defined in WP1 and within the identified cost and schedule constraints according to project management WP8). They are key elements of the project conception loop. After an initial kick off meeting, they are conducted annually. Each partner will provide their results and TECH will provide overview of the project and main orientations. Main planning steps will be reviewed during those regular project gates. Input and output of technical work packages will be verified to check for potential project delays. Main technical orientations will be presented during face-to-face meeting with all partners. Discussions will allow a deeper control of main technical choices. Project is still at a very low Technology Readiness Level (TRL). Decisions still have large impacts on the final success of the project. Bee-Plane configuration selected during TRL1 studies has already made enormous improvements in regards of weight and economic impact. Studies that will be accomplished during three years will bring project to a much further level of details. Critical Design Reviews will permit an agile project management and lead open innovation through the conception loop. Task 1.4 is a project management tool. Intermediate deliverables will be used as an input of brainstorming among partners. CDR preparation notes and meeting minutes will provide inputs and orientations into work packages for the following year of studies.

During CDR1 (M12), first mechanical analysis and initial aerodynamic and acoustic performance will be reviewed. CDR2 (M24) will close TRL2 level of the project. During CDR2, advanced simulation studies (WP2 and WP5) will be analysed in relation with advanced design of the complete aircraft, detachable fuselage, internal structure and equipment (WP3 and WP4). CDR3 (M36) provides a final overview of the overall aircraft and detachable fuselage design and critical items to be brought to a future TRL3 phase.

Roles

- TECH will be the technical and scientific coordinator in these reviews.
- All partners will provide results and information on tasks, planning and difficulties.

Task 1.5 Innovation summary (M1 / M10-M12 / M22-M24 / M34-M36)

Lead: TECH- Support: ALL

As a concept-plane, Bee-Plane project allows new technologies to be developed and studied. Focussed on regular aircraft and incremental innovation, aeronautical industries will benefit from break-through technologies implemented within Bee-Plane project. A disruptive approach, focussed on ambitious targets, generates new ideas and open innovation. Those technologies might be transferred to regular aircraft. Summary of innovations conducted in task 1.5 has two objectives:

- Establish that Bee-Plane specific detachable architecture is optimal to implement those innovations, compared to regular aircraft,
- Assess new technologies, implemented within Bee-Pane project, that have enough potential, one by one, to be transferred to regular aircraft.

During Bee-Plane TRL1 studies, some innovations have already been selected to be further developed at TRL2

- Triple bubble fuselage including assessment of benefit for a regular aircraft (main wing and fuselage not detachable).
- Mix of propulsion including impact of this innovation on regular aircraft.

Roles

- TECH will prepare the innovation summary on the basis of the results achieved in other work packages taking into account feedback from all other partners.

Deliverables

D1.1 – Aircraft initial overview (M1) **<u>TECH</u>**

Initial technical specifications of the aircraft based on previous studies already achieved, passengers scenario description, updated planning of tasks, main meetings dates.

D1.2 – Initial CDR1 report and aircraft conceptual overview (M12) **<u>TECH</u>**

Updates in aircraft specifications and detachable concept, made according to first year studies achieved by other partners in technical work packages (WP2, WP3, WP4, WP5). D1.2 includes an innovation summary with detailed description of innovations and methodologies that focuses on each partner and tasks done in each work packages.

D1.3 – Intermediate CDR2 report and aircraft TRL2 description (M24) **<u>TECH</u>**

Detailed aircraft description for TRL2, including structure, equipment and mechanism that are suitable for standard operations of airlines and airports. D1.3 includes an innovation summary focussing on TRL2 innovation.

D1.4 – Final CDR3 report and aircraft final description (M36) **<u>TECH</u>**

Project final technical overview (description of a medium range aircraft with one detachable fuselage) that focus on further studies to be achieved (during TRL3 studies) and overall impacts of the concept.

D1.5 – Final innovation Summary (M36) **<u>TECH</u>**

Final list of potentials (technical and economic) innovation and methodologies, developed in Bee-Plane project.

WP2

Work package number	**2**	Start date or starting event:				M1-M36			
Work package title	**Aerodynamic and Acoustic Studies**								
Participant number	1	2	3	**4**	5	6	7	8	9
Participant short name	TECH	ERT	LMS-SAM	**TCD**	ARTTIC	UNINA	MGEP	AED	ISMEP
P.M. per participant	4	3	0	**54,5**	0	20,5	0	0	0

Objectives

The objectives of WP2 are to:

- Specify and perform the necessary aerodynamic and acoustic studies to assess the Bee-Plane design.
- Identify key elements (such as the fastening system, main landing gear, rear tail, detachable fuselage, etc.) where changes are needed to improve the performance of the Bee-Plane. The aerodynamic and acoustic elements must be considered together due to the direct physical relationship between flow and aerodynamically generated noise.
- Through the use of parametric studies provide optimised design information for use in the yearly CDR meetings and the aircraft redesign and optimisation stages.

Description of work

WP2 will begin by assessing the TRL 1 Bee-Plane design from an aerodynamic and acoustic point of view. The outputs of current and past university research projects conducted outside of this project proposal will form the start point for this assessment. Through this process, key areas which require further assessment will be identified. In particular the acoustic studies conducted in WP2 will be the first complete assessment of the design from a noise emission point of view.

With this understanding, existing commercial and available in house software codes suitable for the required analysis will be selected from the available toolsets of the partners. The application of these analysis tools will identify potential improvements to the airframe design through parametric studies of the aircraft parameters. The improvements achieved through these modifications will be assessed in a second phase of the analysis using the updated airframe design.

WP2 therefore consists of four tasks namely: definition of key studies, aerodynamic studies, acoustic studies and the airframe performance assessment. Each of these tasks will have an initial phase starting at the current state of knowledge and a second stage where modifications and improvements will be defined and assessed as input to the yearly CDR meetings of WP1.

Task 2.1 – Definition of key studies (M1-M3)

Lead: TCD - Contributors: UNINA, TECH

This task will begin with a review of Bee-Plane TRL 1 specifications focused on aerodynamic studies in order to identify the main weaknesses and issues to be addressed:

- The existing TRL 1 CAD drawings will be assessed and processed as input for the necessary CFD and numerical studies. For example this may require production of numerical meshes from the Bee-Plane CAD for input in CFD solvers or sound propagation tools.
- The studies will be ordered to provide maximum outputs for interaction with the WP1 CDR meetings at M12, M24 and M36. Analysis tools will be selected from the existing codes and software available to the partners in order to complete required studies that are identified.
- From an acoustic perspective all questions regarding Bee-Plane noise are open. A full study of interior and exterior noise is required to identify the key issues in the current design. The main objective in this task will be to order the acoustic studies to make best use of the available CAD, engine data and modelling tools.

This initial assessment and definition of the studies will be completed by M3 of the project.

Roles

- TCD will review and identify the acoustic studies required within the project, including the appropriate level of detail for source models and analysis of the turbofan and turboprop propulsion systems, airframe including attachment mechanisms and landing gear and turbulent boundary layer noise (using analytical, numerical and database/semi-empirical codes).

- UNINA will identify the overall aerodynamic model of the airframe in order to carry out performance, static stability, control and dynamic derivative characteristics estimations.
- TCD will identify a suitable code (e.g. BEM) for source propagation to the far field such as Sysnoise or in house code with low speed flow models.
- TECH will provide input from the TRL 1 studies and exploit results for WP1.

Task 2.2 – Aerodynamic studies (M4-M24)

Lead: UNINA - Contributors: ERT, TCD

Through the use of CD-Adapco's StarCCM+ CFD software which runs on the supercomputing facility of the University of Naples Federico II, UNINA will set up CFD studies of both the isolated aircraft and detached fuselage as well as the combined aircraft and fuselage module configuration. Complete parametric studies will be performed of the following elements: lift, drag and pitching moment curves definition, lateral-directional aerodynamic curves definition, trim studies. The main performance characteristics of the analysed aircraft configurations will be evaluated and static and dynamic stability derivatives will be extracted. These CFD results will also be utilised for aerodynamic noise assessments in Task 2.3 and the aero-elasticity studies of WP3.

Roles

- UNINA will conduct the aerodynamic assessment of the Bee-Plane with support from ERT.
- TCD will interact with the aerodynamic assessment to provide guidance on key parameters as well as to insure seamless integration with the acoustic studies. In particular the CFD calculations used for the aerodynamic assessment will be taken as input for source models as part of the airframe noise assessment.

Task 2.3 – Acoustic Studies (M4-M30)

Lead: TCD - Contributors: UNINA

The acoustic studies of the Bee-Plane will integrate appropriate tools, listed below, in order to perform a comprehensive noise assessment. The implementation of these tools makes use of in-house codes developed from TCD's past involvement in EU projects and the current literature. These tools require source models for the various noise components, outlined below. These source models are used as inputs for shielding and propagation calculations to assess exterior fly over and sideline noise as well as transmission models to assess interior cabin noise. The approach taken is similar, on a much smaller scale, to NASA's Aircraft Noise Prediction Program (ANOPP2, 2011) [1] which integrates a variety of semi-empirical and numerical source modelling tools with propagation methods to assess the noise performance of future aircraft designs. Similarly DLR has a number of separate tools used for the assessment of novel configurations (Bertsch & co, 2013).

<u>Source Models for Aircraft Noise Components for use on the Bee-Plane</u>

- Propeller: methods to estimate tonal sources from propellers are well developed and generally refer back to (Farassat, 1981) which implement Fowcks Hawkings type sources. These require as input the geometry and operating conditions of the blade surfaces. An efficient example of a computer implementation for subsonic blade approach velocities with off axial inflow conditions is given by Carley, 1998. This formulation has already been applied to the current Bee-Plane design at TCD.
- Landing Gear: highly successful empirical predictions of aircraft landing gear noise have been achieved by Guo, 2005 and Lopes, 2009. TCD will utilise the results of European projects on experimental measurement of landing gear noise in the Clean Sky program namely the ALLEGRA and ARTIC projects which investigate a range of low noise technologies applied to full scale landing gear. These experimental databases will be used with the existing empirical source models to quantify the Bee-Plane landing gear noise.
- Jet: the industrial jet noise predictions have successfully been made with the application of the model proposed by (Tam & Auriault, 1999). This model relates the local turbulent kinetic energy to the local pressure fluctuations of the small scale turbulence and requires knowledge of the turbulent length and time scales which can be acquired either from a CFD calculation (O'Reilly & Rice, 2010), an experimental database or be modelled empirically (Kennedy & Breaky, 2013). TCD has access to a number of experimental and numerical databases of jet noise from the JEAN and CoJen projects suitable for use in jet noise modelling of the Bee-Plane.
- Fan: the fan noise investigation will utilise engine manufacturer data in combination with an intake flow simulation from the aerodynamic studies. The fan noise studies will be conducted following optimisation of the engine intake design when a suitable source model can be selected. In this case as the proposed engine features a novel embedded fan and an appropriate analysis tool will require development referenced to current methods (ANOPP2 etc.).

- Turbulent Boundary Layer (Airframe noise): numerous empirical models exist that provide the turbulent boundary layer wall pressure cross spectrum used as an input to model the response of an aircraft panel. (Rocha and Palumbo, 2012) have investigated the sensitivity of these models which are usually dependent on four parameters: the reference power spectrum, the flow convective velocity, and the coherence lengths in streamwise and spanwise directions. The CFD preformed for the Bee-Plane aerodynamic studies will be used as input to these models as input for the cabin noise assessment.

Airframe Noise Shielding Assessment

Novel aircraft designs often favour propulsion systems which are shielded from ground observers by the intervening airframe structure with intakes on the upper surfaces. Acoustic shielding effects will be calculated for the Bee-Plane by solving an external acoustic scattering problem for a moving aircraft. In (Agarwal et al, 2007), acoustic shielding effects of the Silent Aircraft airframe are quantified by a ray-tracing method. The dominant frequencies from the noise spectrum of the engines are sufficiently high for ray theory to yield accurate results. From Fermat's principle it is clear that classical Geometrical Optics and Geometrical Theory of Diffraction solutions are applicable to this moving-body problem as well. The total amount of acoustic shielding at an observer located in the shadow region is calculated by adding the contributions from all the diffracted rays (edge-diffracted and creeping rays) and then subtracting the result from the incident field without the airframe. These methods have been verified by experiments and will be applied to the Bee-Plane with and without the basket to assess the shielding benefit of the configuration.

Aircraft Fly-over Auralization

While quantitative, the standard aircraft noise metrics provide no sense of the sound characteristics as heard by a listener on the ground. In order to provide stakeholders with a more understandable measure of the Bee-Plane flyover noise a different approach is required. The ability to auralize, i.e., render to audible sound, a simulated flyover has multiple benefits. It provides another means of expressing the societal benefit of low noise concepts to stakeholders in a form that is inherently understandable. The state of the art in auralization of these flyovers under various operational conditions is well described by (Rizzi et al, 2013). This work develops auralization methods suitable for use with system noise prediction tools and applies to novel aircraft configurations. Source directivity data from an engine noise modelling application from NASA's ANOPP toolset serves as an input for the source noise synthesis. Propagation of the resulting pressure time history to observer locations is performed incorporating shielding and Doppler effects and finally, auralizations combined with visualization are provided for to allow one to experience the flyover from the perspective of a listener in the simulated outdoor environment. TCD has considerable experience generating auralizations for urban transport noise problems and the application of these tools to the Bee-Plane will provide a novel dissemination tool for the project.

Cabin Noise Transmission Assessment

In addition to exterior noise, it is also essential to estimate the internal cabin noise to assess the viability of a design particularly when there are tonal sources. The inflight experience of Bee-Plane passengers will be investigated in this assessment. (EDU 07001, 2007) provides a robust means of estimating the reduction in noise levels through a fuselage wall with or without cabin wall trim. The prediction method is based on the power flow approach and is intended for application to the radiation of both tonal and broadband noise from various types of aircraft engines into the aircraft cabin. The inputs required are the cabin geometry, material properties, trim properties and acoustic and structural loss factors.

Roles

- TCD will conduct the noise assessment for the Bee-Plane. The first year of the project will focus on the propeller and landing gear noise assessments, year two will focus on the fan, jet and airframe noise assessments and year three will focus on the transmission, propagation and auralization problems.
- UNINA will support this task through providing the necessary CFD resulting from the aerodynamic studies.

Task 2.4 – Airframe Performance Assessment (M12-M36)

Lead: TCD - Contributors: UNINA - Support: TECH

- The results from the aerodynamic and acoustic studies will be collated to assess the potential improvements to the aircraft design in terms of achieved noise reduction and improved flight efficiency. The expected noise level will be compared to ICAO standards.
- Aircraft parameters will be assessed through a meta model generated from the results the of the parametric studies of T2.2, T2.3 and T2.4 with the baseline design as a reference. This model will be used to propose optimised alterations to the aircraft geometry in terms of both aerodynamic and acoustic performance.

Roles

- TCD will assess the acoustic performances.
- UNINA will assess the aerodynamic performances.
- TECH will collect the results for WP1.

Deliverables

D2.1 – Initial aerodynamic and acoustic performance review (M12) **TCD**

This deliverable will compile the results of the first year in terms of the initial aerodynamic and acoustic studies for use in the WP1 CDR meeting at M12.

D2.2 – Aerodynamic assessment of Bee-Plane design (M24) **UNINA**

This deliverable will assess the aerodynamic efficiency of the aircraft compared to conventional configuration, and identify design issues that determine the effectiveness of detachable concept performance (as wing size, aircraft payload capacity, drag, etc.).

D2.3 – Advanced aerodynamic and acoustic performance review (M24) **TCD**

This deliverable will compile the results of the second year in terms of advanced aerodynamic and acoustic studies for use in the WP1 CDR meeting at M24.

This deliverable contains the results of a parametric study of Bee-Plane configurations for flight performance.

D2.4 – Interior and Exterior noise assessment of Bee-Plane design (M30) **TCD**

This deliverable will collate the results of the complete interior and exterior noise assessment of the Bee-Plane including industry standard noise metrics and auralizations for use in dissemination activities.

D2.5 – Final review of modifications for improved aerodynamic and acoustic performance (M36) **TCD**

This deliverable will compile the final results of the aerodynamic and acoustic studies and recommendation for aircraft optimisation for use in the WP1.

WP3

Work package number	**3**	Start date or starting event:				M1-M36		
Work package title	**Aerostructure**							
Participant number	1	2	3	4	5	6	7	**8**	9
Participant short name	TECH	ERT	LMS-SAM	TCD	ARTTIC	UNINA	MGEP	**AED**	ISMEP
P.M. per participant	2	2	0	2	0	0	56,7	**91,9**	0

Objectives

The main objective of WP3 is to develop a 3D design and dimensioning of the full aircraft, composed by the airplane (upper structure) and the detachable fuselage which fulfils the following specifications:

- Maximum weight of 100 t with optimum gravity centre distribution,
- Geometrical restrictions for aerodynamic performance.

Description of work

The detailed objectives of WP3 are to:

- Define the key elements of the aircraft structure,
- Assess main equipment integration,
- Select optimal materials according to wings and fuselage constraints in relation with flight conditions. Lightweight and costs issues will drive the corresponding design activities,
- Assess structural weight of airplane and detachable fuselage.

Conceptual design will achieve a preliminary design and the dimensioning of the structure including a first study of the most suitable materials for the proposed geometry. Final design and results from a dynamic analysis and the structural analysis will also be performed in cooperation with WP5.

Detailed Design on the basis of the conceptual design of both structures will be done.

A final sizing will be performed for different loading cases using previous data and different calculations iterations. Then, aeroelastic studies will be conducted to identify wings structural weakness. Studies will take into account loads from turbo propeller engines, specific main landing gear configuration, dedicated design of the central beam, and position of fastening system.

TASK 3.1 CONCEPTUAL DESIGN (M1 – M12)

Lead: AED – Contributors: MGEP, TECH – Support: UNINA and LMS-SAM

Task 3.1 will focus on preliminary design and dimensioning of the structure, both aircraft and detachable fuselage. Moreover, a first approach will be performed concerning the study of the most suitable materials for the proposed geometry. At this stage the impact and changes required in the calculation and design methodology derived from different structural configuration of both aircraft and detachable fuselage with respect to a conventional aircraft will be studied.

Note that the main differences between these two fuselages and conventional fuselages are:

- Upper rear aircraft fuselage is not subjected to pressurization,
- Detachable configuration entry point loads on the detachable fuselage.

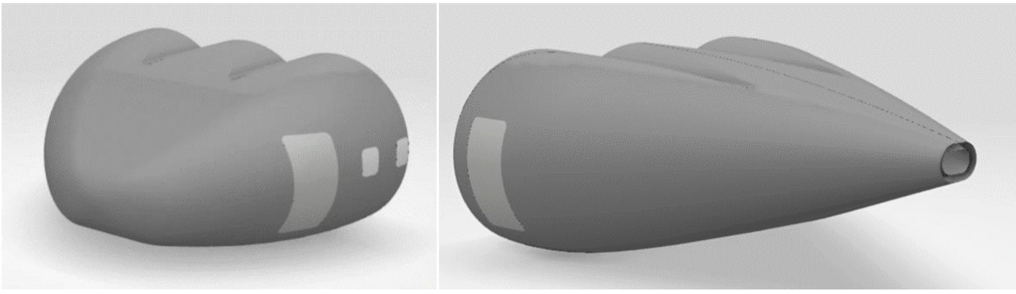

Figure 25: Preliminary design of the front and the back of the detachable fuselage (Supmeca, 2014)

STRUCTURE DESIGN (M1-M9)

The first drawings of the structure will be performed in NX v7.5 based on the data from the previous tasks and in parallel with the structural analysis. Materials and dimensions used in the design will be provisional values, to be confirmed in the detailed design phase.

- Interface documents generation,
- Preliminary basic lines definition,
- Structural concept definition.

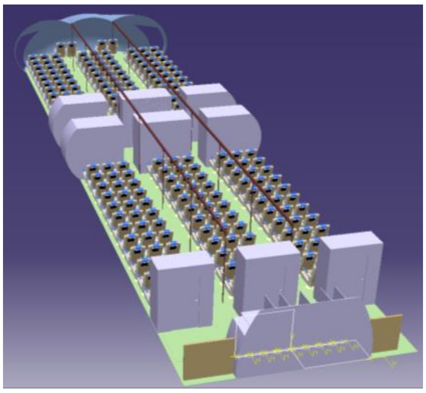

Figure 26: Passenger detachable fuselage (ESTACA, 2014)

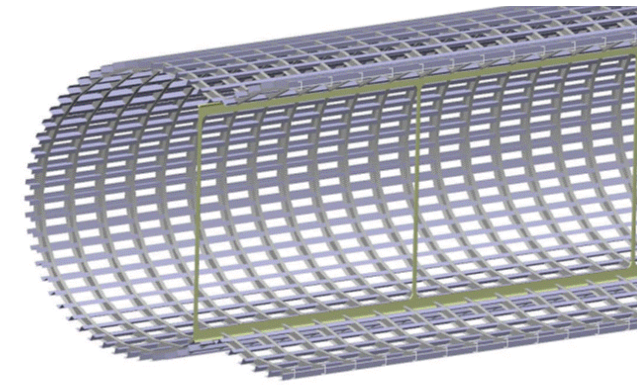

Figure 27: Internal structure of detachable fuselage (Supmeca 2014)

STRUCTURAL ANALYSIS (M4-M12)

Based on the initial design and specifications of the aircraft and the detachable fuselage provided by WP1, AED CAE department, employing the specific aeronautical methodology for structural analysis, will perform a first dimensioning and distribution of both structures. This task will interact with the preliminary design and the materials and manufacturing departments in order to establish the initial guidelines as a basis for the preliminary design. In this task the following subjects will be developed:

- Design criteria to be meet by the structure,
- Calculation methods and procedures, generation of spread sheets,

- Generation of preliminary geometry models for FEM calculations to be provided for aircraft mechanical calculation (WP5) and for aerodynamic analysis (WP2).

Roles

- AED will produce numerical mock mock-up of the complete aircraft and detachable fuselage.
- MGEP will establish multimaterial structure sizing.
- TECH provides design guides and technical requirements.
- UNINA provides initial equipment interfaces and LMS-SAM provides initial mechanical simulation results.

TASK 3.2 DETAILED DESIGN (M12 – M36)

Lead: AED – Contributors: MGEP, ERT, UNINA – Support: LMS-SAM

Task 3.2 will focus on the detailed design and dimensioning of both structures. For that purpose, interaction with WP2, WP4 will be required to be provided with aerodynamic drag data over the fuselage, vibroacoustic performance as well as landing gear geometry detail and loadings (to be assembled in the BEE's structure), attaching system to be assembled in both, the aircraft and the detachable fuselage with the preliminary data. Based on the provided geometry and load data different calculation iteration, a final dimensioning of both the aircraft and the detachable fuselage will be performed for different loading cases. This part of the task will be performed together with WP5 where performance of the whole aircraft (aircraft + detachable fuselage) will be verified under different scenarios (landing, cruise flight, etc.).

STRUCTURAL ANALYSIS (M12 – M30)

After the preliminary design phase, the AED CAE department will deal with the final dimensioning of the critical structures using values from the material characterization. The following tasks will be developed:

- Analysis of the structure under defined load cases,
- Stress calculation,
- Comparison and analysis of the results.

STRUCTURE DESIGN (M21 – M36)

The AED CAE department will provide a final design based on the previous design and the values of the structural analysis. This final design, at TRL 2, should enable the manufacturing of a prototype:

- Interfaces definition,
- Detailed numerical mock-up and drawing generation.

AEROELASTICITY STUDIES (M18-M30)

Lead: UNINA - Contributors: TCD, ERT

- Quasi static flow calculations on the structures will be repeated under candidate deflection modes to provide differential information on the fluid loading. These will then be used in a small dynamical model incorporating fluid memory effects to assess the operating limits of the design and guide further optimisation of the structure.
- Static and dynamic aeroelastic stability of the aircraft structure will be investigated with reference to inertial and layout configurations believed to be more significant. Analyses will be performed in compliance with applicable airworthiness requirements and by adopting theoretical modes association only.

All aeroelastic analyses will be performed using SPANWISE-AeroeLAB software V. 3.0. Since the tool is not commercially distributed yet, a short description of its main properties, functionalities and test-cases seems to be mandatory.

SPANWISE-AeroeLAB code has been developed and upgraded within last twenty years with the intent of providing an excellent and reliable tool for static and dynamic aeroelastic and aero-servo-elastic analysis of aircraft (A/C).

Rational approaches and validated numerical methods, compliant with EASA standards CS-25 and CS-23, have been implemented in a multidisciplinary computational environment able to accomplish the following main tasks:

- Generation of A/C dynamic model (structural model and inertial model);
- Generation of A/C aerodynamic model;
- Generation of accurate transfer matrices interfacing between dynamic and aerodynamic models;
- Evaluation of A/C acceleration and loads response due to manoeuvre and/or gust;

- Evaluation of A/C static and dynamic acceleration and loads response to movable lifting surfaces deflections imposed by mechanical and/or electro-mechanical control circuits;
- Evaluation of divergence, control reversal and flutter speeds.

The computational tool, and the numerical methods within implemented, assure fast analyses aimed also to investigate the influence of several design parameters on A/C aeroelastic behavior; in other terms, it is provided the capability of fast sensitivity aeroelastic analysis in correspondence of variations in structural and dynamic properties pertaining to A/C components including also the integrated control circuits.

Software overall facilities and performances have been positively tested during certification processes of several aircraft in relation to aeroelastic issues; in the following table main examples of software practical applications (test-cases) have been listed.

Aircraft	Company	Software application
ATR-42	Aerospatiale-Alenia Aeronautica	Flutter analysis (by means of numerical and experimental modes) aimed to prove aircraft compliance to CS-25 airworthiness requirements
ATR-72		
P180	Piaggio Aero Industries	Gust response analysis and aeroelastic instabilities evaluation according to CS-23 requirements.
P166	Piaggio Aero Industries	Flutter analysis (by means of numerical and experimental modes) aimed to prove aircraft compliance to CS-23 airworthiness requirements
P68	Partenavia	
VF600W	Vulcanair	
Skycar	OMA SUD	

Roles

- AED provides detailed numerical mock-up of the complete aircraft and detachable fuselage.
- MGEP refine material selection based on stress results and weight assessment.
- UNINA provides numerical mock-up on main equipment and conduct Aeroelasticity studies.
- LMS-SAM provides results on mechanical simulation based on initial numerical mock-up.
- TECH provides technical overview according to other work packages results (WP2, WP4 and WP5).

Deliverables

D3.1 –Design criteria and procedures (M4) **<u>AED</u>**

D3.1 describes the definition of design criteria and calculation to be met by the structure and to be followed in the project. The deliverable will define an aircraft structural configuration and the procedures currently used in design to define structural elements suitable for demonstrating new approaches.

D3.2 – Basic Lines and ICD's (M6) **<u>AED</u>**

D3.2 will provide first numerical mock-up for aircraft and detachable fuselage structures. The basic lines will be the input to start with the WP 3 and WP5.

D3.3 – Preliminary structural concept and FEM (M12) **<u>AED</u>**

D3.3 will define the structural concept taking into account the first analysis results and the AED experience. The first analysis by FEM to define the preliminary sizing will be completed. This first FEM analysis will be done with the Basic Lines, and preliminary loads.

D3.4 – Detailed CAD Mock-up and final FEM (M24) **<u>AED</u>**

D3.4 will include the final FEM analysis. This analysis will be done with the detailed design including the revised sizing. This FEM will represent the relevant structural elements in much greater detail.

D3.5 – Assessment of Bee-Plane static and dynamic aeroelastic stability (M30) **<u>UNINA</u>**

D3.5 will provide interactions between the inertial, elastic and aerodynamic forces that occur when the aircraft and detachable fuselage are exposed to the air flow. Analysis will be conducted on aircraft only, detachable fuselage only and complete aircraft with comparison to standard aircraft.

D3.6 – Stress Reports (M32) **<u>AED</u>**

D3.6 will define the stress report final (manual analysis and FEM analysis).

D3.7 – Detailed CAD drawings (M36) **AED**

In D3.7 final detailed CAD drawings will be presented for aircraft and detachable fuselage, including detailed interface with main equipment.

WP4

Work package number	**4**	Start date or starting event:				M1-M36		
Work package title	**Equipment Design**							
Participant number	1	2	3	4	5	**6**	7	8	9
Participant short name	TECH	ERT	LMS-SAM	TCD	ARTTIC	**UNINA**	MGEP	AED	ISMEP
P.M. per participant	5	26	0	0	0	**36**	0	0	0

Objectives

The objectives of WP4 are to:

- Design the main and rear landing gear,
- Design the locking system of detachable fuselage,
- Assess main equipment integration.

Conceptual design will achieve a preliminary design and the dimensioning of the structural component of equipment, in cooperation of WP1, WP2. Low noise solutions will be integrated on landing gear in order to reduce the noise in the landing phase. Actuation and kinematic chain will be provided to mechanical simulation tasks (WP5). In collaboration with WP3, a design of locking system of detachable fuselage will be done.

Description of work

TASK 4.1 MAIN LANDING GEAR (M1 – M30)

Lead: UNINA – Contributors: ERT, TECH – Support: TCD, AED, LMS-SAM

Based on the initial design and specifications of the aircraft (position of gears, size, mechanical constraints and weight) provided by WP1, task 4.1 will begin with a preliminary design of the main landing gear, and a kinematic chain. Actuation, dampers, cabling, brake and cooling system, will be defined as a preliminary in order to check the integration on the airplane; then a detailed design will be done.

3D CAD file will be release, in order to perform a detailed structural and kinematic analysis.

Detailed design of a kinematic chain will be performed in collaboration with WP5.

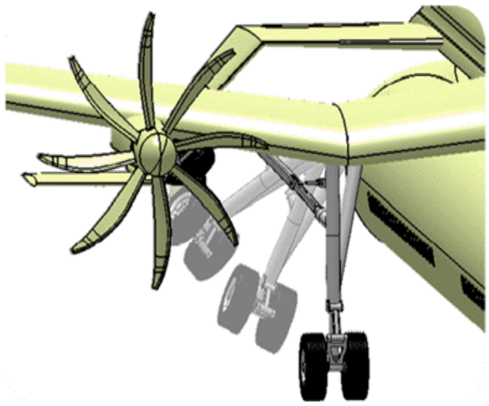

Figure 28: Main landing gear (Supmeca, 2014)

Roles

- UNINA will provide aero expertise in the definitions and design of low weight structure.
- ERT will develop the geometric characteristics and provide the definitions of main equipment.
- AED will provide aircraft structural numerical mock-up.
- LMS-SAM will establish main mechanical simulation and stress fields at landing situations.
- TCD will provide input based on the landing gear noise assessment of WP2 as well as advice on potential low noise designs.

TASK 4.2 LOCKING SYSTEM (M1 – M30)

Lead: UNINA – Contributors: ERT, TECH - Support: LMS-SAM

Task 4.2 will focus on design of locking system for the detachable fuselage; a 3D CAD file of locking system will be release.

The issues that will be analysed are:

- Separation and fastening processes of the fuselage and the aircraft: this is a critical aspect, the system will be developed considering the alignment problems from aircraft and detachable fuselage, in order to reduce the process time, and reduce the risk of this operation.
- Reliability of the locking system: the system will be designed in order to avoid any problem during flight manoeuvre; redundancy system will be designed.

In this task, initially, different locking system (hydraulic, pneumatic, mechanical) will be analysed in order to not overlook any solution; then in collaboration with the WP1, WP3 and WP5 one solution will be chosen and then UNINA and ERT will develop the solution in all the details (mechanical, separation and fastening process); 3D CAD file will be release, in order to perform a detailed structural and kinematic analysis.

Roles

- UNINA will establish locking system specification and define preliminary and functional design.
- ERT will provide detailed mechanism and numerical mock-up (3D cad file).
- TECH will assess system performance and feasibility related to airport operations.

TASK 4.3 REAR LANDING GEAR AND TAIL (M1 – M30)

Lead: UNINA – Contributors: ERT, TECH, Support: TCD

Based on the initial design and specifications of the aircraft (position of gears, size, mechanical constraints and weight) provided by WP1, task 4.3 will begin with a preliminary design of the main landing gear, and a kinematic chain. Actuation, dampers, cabling, will also be defined as part of the preliminary design.

Then, after the CDR at M12, in order to check the integration on the aircraft, a detailed design will be done; the detailed design of a kinematic chain will be performed in collaboration with WP5. Particular attention will be given.

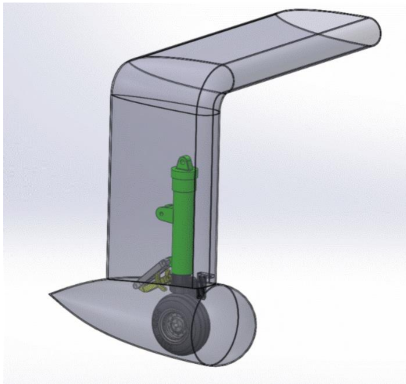

Figure 29: Right rear directional landing gear (IFMA, 2014)

Roles

- UNINA will establish design and mechanical specification based on aeronautical standards. Also UNINA will provide aero expertise in the definitions and design.
- ERT will develop the geometric characteristics and provide the definitions and provide detailed mechanism and numerical mock-up.
- TECH will assess system performance according to ground operations and landing situation.

TASK 4.4 OTHER EQUIPMENT AND AIRFRAME SYSTEMS (M12 – M36)

Lead: TECH – Contributors: ERT, UNINA

The objective is to focus on other equipment and systems needed on the aircraft and detachable fuselage (as APU, integrated modular avionics, cockpit, hydraulic and fuel pumps, actuations systems, etc.). List of equipment will be detailed and basic integration within numerical mock-up will be done. Weight impact will be provided to the structural design team (WP3).

Roles

- TECH will provide list of equipment, technical specifications and dimensions.
- UNINA will verify system integration.
- ERT will provide basic numerical mock-up to be integrated within aircraft and fuselage numerical mock-up.

Deliverables

D4.1 – Preliminary design of Equipment (M6) **UNINA**

This deliverable provide initial equipment configuration with basic numerical mock-up.

D4.2 – Conceptual design of Equipment (M12) **UNINA**

With first analysis results, the preliminary equipment configuration will be completed. Interface with aircraft and detachable fuselage are refined. Basic mechanism of main functions is designed.

D4.3 – Advanced design of Equipment (M18) **UNINA**

Configuration of main equipment is provided with detailed main mechanism focussing on mechanical issues.

D4.4 – Detailed design of Equipment for TRL2 (M24) **UNINA**

Mechanical configuration of main equipment is provided. Basic hydraulic systems are designed.

D4.5 – Improved design of Equipment (M30) **UNINA**

Updated configuration is numerically described including mechanism, hydraulic system and main electric needs.

D4.6 – Final design of Equipment (M 36) **UNINA**

Final equipment numerical mock-up is provided and integrated within final aircraft design.

WP5

Work package number	**5**	Start date or starting event:			M7-M36				
Work package title	**Mechanical simulation**								
Participant number	1	2	**3**	4	5	6	7	8	9
Participant short name	TECH	ERT	**LMS-SAM**	TCD	ARTTIC	UNINA	MGEP	AED	ISMEP
P.M. per participant	3	0	**36,5**	0	0	0	0	0	0

Objectives

The objective of WP5 is to evaluate the Bee-Plane concept feasibility using digital simulation to provide the levels of load which the plane can endorse and its lifetime for the given design.

WP5 will say if the design or a part of it has to be modified, in particular potentially weak parts (wings, connection design, fasteners, fuselage, etc.) and if dimensions are well chosen. Within the conception loop, some parts may have to be reinforced by increasing thickness, for example, or modifying design.

Description of work

Former WPs (WP1 to WP4) have designed a model of the plane in terms of shape, dimensions, material used, thicknesses of all structural parts, connections between parts and mechanisms.

WP5 will assess ability of the design to face reality and ability to withstand tough environments (shocks at landing on, taking off and in flight steps, many cycles of use, weather, speed, air pressure, etc.). The simulation step will create a Bee-Plane similar model on computer and make it face a simulated reality. This is the goal of Finite Element Analysis (FEA), a computing method widely used in industry for years.

The environment (heat, speed, friction, ground, air pressure, aerodynamic forces, loads induced by repeated cycles of connection and disconnection, etc.) will be defined according to different operation modes: rolling on the tarmac, landing, taking off, connection and disconnection of the removable fuselage.

Computations are to be set up according to data and information given by WP1 to WP4 contributors:

- Static loads: weight when empty, weight when full, etc.
- Boundary conditions: friction with the ground, temperatures on ground and on air, pressures.
- Dynamic loads: wings vibrations on flight, frequencies and amplitude of movements induced by motors, shocks induced by critical moments as landing or taking off, etc.
- Kinematic effects in mechanisms of articulated links and joints: loads and stresses created by connection and disconnection moves.

Starting from the WP1 to WP4 geometry and design drawings files, WP5 builds the numerical model and computes mechanical behaviour of the plane.

WP5 will help in validating the design and dimensions choices, and can lead to slight or serious modifications while analysis of results has been carried out: stresses, strains, eigenvalues, dynamic response, etc.

This computation step will use static, dynamic and kinematics computation theory and computing tools (SAMCEF Mecano, non-linear analysis dedicated software of LMS Samtech).

TASK 5.1 STUDY OF LANDING SITUATION (M7-M31)

Lead: LMS-SAM – Contributors: TECH – Support: TCD, AED, UNINA

Task 5.1 will focus on computing stresses and strains supported by the structure during the landing step:

- Creation of an equivalent simplified model of the landing gear: WP4 provides a detailed first design of the landing gear. At WP5 step, it is simplified as special equivalent finite element (behaviour, stiffness, mass) made of beams, kinematic joints, springs. Loops between WP4 participants and WP5 participants will refine the model in order to obtain the most faithful model.
- Mesh of the whole structure: Plane and detachable fuselage are meshed as shell elements and reinforcements are meshed as beams. Dimensions, material and stiffness are provided by WP1 to WP4 participants. The equivalent landing gear model of task 1.1 is added. A first static analysis is achieved in order to validate this first model. Load applied is the weight of plane full one with passengers.
- Computation of the stress field when front wheels make contact with the ground: The force induced must be evaluated according to the weight, the speed and reactions of ground. The shock creates a dynamic stress field which is transmitted to the wings of the plane and to all the structure. Values are computed through a non-linear Finite Element Analysis (FEA).
  - Both wheels make contact simultaneously: the field is homogeneously distributed over the two wings,
  - Wheels make contact separately: one wing is impacted first alone and then the other wing.

  The job consists in choosing the appropriate data parameters in order to properly describe the non-linear phenomenon, make sure the computation converge to valid results. Launching many computation sessions is necessary to refine the data setting.
- Computation of the stress field when the rear wheels make contact with the ground: Plane is still submitted to the stress field induced by front wheels landing. A second impact is induced while rear wheels reach the ground depending on former situation (both front wheels together on ground or successively). Both scenarios are studied. Non-linear Finite Elements Analysis computations are to be made. Choice and refining parameters are achieved. Stresses and strains supported by plane are computed. The capacity of plane to endure those stresses value is evaluated and, if answer is no, appropriate modifications are proposed.

Role

- LMS-SAM will do the simulation work.
- TECH will coordinate studies in connection to aircraft design (WP1).
- TCD will coordinate studies linked with aerodynamic behaviour (WP2).
- AED provide structural numerical mock-up (WP3) and UNINA provide main equipment design (WP4).

TASK 5.2: STUDY OF DYNAMIC AND STATIC BEHAVIOUR OF FASTENERS AND CONNECTION MECHANISMS (M7-M31)

Lead: LMS-SAM – Contributors: TECH - Support: AED, UNINA

The detachable fuselage is linked to the plane through alignment and lock systems. Their capacity to resist at connection situation must be insured. The mechanism of locking and unlocking must be still secure after many uses. Dynamic computation and Fatigue computation are to be managed. Dynamic computation gives the level of stresses and strains induced in the model. Numerical values of these stresses and strains, and iso-colors (from the lower value in green to the upper value in red) distributed over the model, let us know exactly what any zone is facing. Fatigue computation gives the lifetime of the mechanism in term of number of cycles of use, number of hours of functioning.

- Modelling and computing the alignment step: The detachable fuselage will move at a given speed to connect with the plane. The first step of connection must insure the alignment of both detachable fuselage and plane. This creates an impact which has to be measured in terms of stresses induced, level of impact. The parts must stay safe and secure. In terms of computation, this situation requires a non-linear dynamic and kinematic analysis, in order to evaluate the system capacity to resist. From the first alignment operation and then to how many operation steps it can insure, i.e. the lifetime and the fatigue analysis. Modifications of dimensions and design could be proposed until appropriate design is accepted.
- Modelling and computing the sliding motion of the locking mechanism: Once the alignment is achieved, the locking mechanism slides to be embedded in its housing. A kinematics and dynamic analysis must be done, giving stresses due to friction and to setting in thrust. This step is to be repeated many times, so a fatigue analysis is necessary.
- Modelling and computing the blocking and screwing of the system of tightening: This step creates stresses and strains which the system must endure. Their values are computed through a non-linear structure analysis and compared the acceptable maximum value.

Roles

- LMS-SAM will do the modelling and computing work.
- TECH will coordinate studies in connection to aircraft design (WP1).
- UNINA will provide detailed numerical mock-up of fasteners and connection mechanism (WP4).
- AED will provide structural design surrounding the connection system (WP3).

TASK 5.3: STUDY OF UNEXPECTED SITUATION AS NON-OPENING OF LANDING GEAR (M7-M31)

Lead: LMS-SAM – Contributors: TECH -Support: TCD, AED, Unina

In that case, the plane has to land without landing gear. This extreme situation will submit the fuselage to cracking or rupture risks. The capacity of the plane to support this situation will be analysed by means of crash computation tools, also managed by SAMCEF FEA software.

- Evaluation of useful data and different scenarios: Speed, altitude, angle of landing, first surface in contact, friction values of ground are the data to be defined.
- Computation of scenario 1 – Front contact: The first surface in contact with the ground is the front part of fuselage. The damage caused is computed in terms of maximum stress value on impact surface. The admissible maximum stress is known so we can determine if failure will occur. For a given design, the limits of the plane will be known.
- Computation of scenario 2 – Rear contact: The first surface in contact with the ground is the rear part of fuselage. Computation and approach are same as previous task.

Roles

- LMS-SAM will do the evaluation and simulation work.
- TECH will coordinate studies in connection to aircraft design (WP1).
- AED will provide aircraft and detachable fuselage numerical mock-up (WP3).
- UNINA will provide main landing gear design and mechanism (WP4).

Deliverables

D5.1 – Stress field at landing phase for initial design (M24) **LMS-SAM**

Listing of maximum values of stress and zones involved, field of stresses on model.

Report explaining the results, defining the maximum admissible values of the initial design.

D5.2 – Stress field at landing phase for final design (M31) **LMS-SAM**

Listing of maximum values of stress and zones involved, field of stresses on model.

Report explaining the results, defining the maximum admissible values of the final TRL2 design.

D5.3 – Stress field at connection phase for initial design (M24) **LMS-SAM**

Listing of maximum values of stress and zones involved, field of stresses on model.

Report explaining the results, defining the maximum admissible values of the initial design.

D5.4 – Stress field at connection phase for final design (M31) **LMS-SAM**

Listing of maximum values of stress and zones involved, field of stresses on model.

Report with results, defining the maximum admissible values of the final TRL2 design, lifetime of connection, alignment and tightening system.

D5.5 – Stress field at landing phase without landing gear (M31) **LMS-SAM**

Listing of maximum values of stress and zones involved, field of stresses on model.

Report presenting the results, defining the maximum admissible values of the final TRL2 design and situation.

WP6

Work package number	**6**	Start date or starting event:			M1-M36			
Work package title	**Impacts on ground operations and processes**							
Participant number	1	2	3	4	5	6	7	8	**9**
Participant short name	TECH	ERT	LMS-SAM	TCD	ARTTIC	UNINA	MGEP	AED	**ISMEP**
P.M. per participant	7	0	0	0	0	0	0	0	**62**

Objectives

The objectives of WP6 are to:

- Define the Main scenarios of Bee-Plane integration in various Airports.
- Create an Integration and Evaluation Methodology.
- Set up Bee-Plane-Airport Change propagation models and mechanisms.
- Define Business models of Bee-Plane-Airport and commercial companies for the main retained scenarios.

Description of work

WP6 will study the potential impacts of operating Bee-Plane on airport infrastructures, including the definition of processes for ground operations and their management. By infrastructure, we mean the structural layouts of the airport (buildings, tarmacs, runway, etc.) and the associated operations that will support the service, materials and human required for dealing with Bee-Planes. The processes concern different kinds of flows linked to airports: i.e. aircraft, detachable fuselage, passengers, luggage, and freight. The integration of Bee-Planes in an airport will impose changes in the structure of the airports and their runways. The adapted structure of the airport and its runway will be defined by some key performance indicators (e.g.: economic, temporal or environmental indicators). These indicators have to be measured and simulated. Benchmarks will be set up in order to compare the performance of the Bee-Plane-Airport as a whole before and after the integration for various scenarios. The differences will allow recommendations for design/manufacturing of Bee-Planes and adaptation/design of airports.

TASK 6.1 DATA AND REQUIREMENTS COLLECTION (M1 – M9)

Lead: ISMEP – Contributors: TECH

Once the aircraft is parked and chocks are put in place, there is the sequence of ground operations carrying-out to service the aircraft between two flights. Suppliers and sub-contractors are involved in this turnaround process making it complex requiring a lot of synchronisation in short and highly constrained time slots. It is for instance the organization of loading and unloading passengers and baggage, safety and security checks, catering replenishment, cleaning and the completion of essential post and pre-flight administration. All these processes are defined and well-tuned for traditional aircraft but they have to be analysed and re-designed, where necessary, for Bee-Planes. Problems of organization, planning and optimization associated with this new configuration should be formulated and tested using simulated models. Ground operations for different aircraft in realistic conditions have to be studied in order to be transposed to Bee-Plane turn-around process. The task is divided into 3 sub-tasks.

- Survey of academic works on airport logistics management: Focus on ground operations and processes including passengers and baggage loading/unloading, catering, cleaning, etc. and identify what is specific to traditional aircraft vs. Bee-Plane model. Related issues concern, among others, operations scheduling, resource assignment, and vehicle routing problem.
- Official documents collection: Identify all directives, regulation and guidelines about air navigation and airport management affecting directly ground operations.
- Airports' data collection: Define ground operations scenarios in existing airports and identify major turning points to new airport requirements dedicated to Bee-Plane though audits.

Roles

- ISMEP will collect and analysis data.
- TECH will provide requirements and make analysis in connection with concept specifications (WP1).

TASK 6.2 SCENARIOS IDENTIFICATION (M6 – M12)

Lead: ISMEP – Contributors: TECH

The four basic possibilities for Bee-Plane integrations are:

- Adaptation. No infrastructure modifications are required in the airport; only ground operations and processes have to be adapted.
- Minor upgrade. Together with the processes and operations (re)design, the airport infrastructures have to be smoothly modified. Their structured should be improved.
- Major upgrade. The airport infrastructures have to be upgraded deeply.
- New dedicated airports. New airports have to be designed in this scenario.

All these situations allow defining the heavy-trends scenarios according to the run of airports (small, medium and large) and air companies. Each scenario will be modelled formally by defining (1) the structural definition, (2) the functional definition and (3) the processes performed by the related actors. Each scenario will be defined and described in such a way that the analysis and performance evaluation should be possible in the further steps of WP6.

Roles

- ISMEP will identify and develop scenarios.
- TECH provide initial business model and will refine analysis according to evolution in aircraft capacities.

TASK 6.3 ANALYSIS MODEL AND EVALUATION (M10 – M33)

Lead: ISMEP – Contributors: TECH

By using the design data (WP1), the requirements book (Task 6.1) and the adopted scenarios (Task 6.2), the objective hear is to model these scenarios, to define relevant KPIs (Key Performance Indicators) for the benchmark of the scenarios, and to evaluate the performance of Bee-Plane integration for each scenario.

The manipulated models should be scalable in terms of temporal horizon (strategic, tactical and operational), granularity of the considered structural and functional components, and granularity of used data. The different steps to ensure will be as follows.

- KPI definition: Define relevant KPIs, according to the identified scenarios, thanks to the interview with actors of ground operations management.
- Generic model construction: Define a generic multi-scales model to cover decisions on different temporal, structural, functional and data scales. The models' scales should be defined according to the lifecycle of planes and airports. Scaling mechanisms should also be defined to browse models.
- Evaluation models: Propose or adapt evaluation models using tools such as simulation or formal techniques (petri net, markovian models, etc.) by considering different kinds of problems identified: location, layout definition, scheduling, resource assignment, and vehicle routing problem.
- Multi-criteria comparison: Analyse the results using multi-criteria techniques and propose the corresponding recommendations for Bee-Plane's design (WP1, WP2 and WP3).

Roles

- ISMEP will establish models and evaluate concept performance.
- TECH will assess results according to industrial constrains (airports and airlines).

TASK 6.4 CHANGE PROPAGATION MODEL (M13 – M24)

Lead: ISMEP – Contributors: TECH

During the design of Bee-Plane, each decision may have impact on the infrastructure and its management. The key idea in this task is to model and characterize the impact of possible variations (called a *change*) of a Bee-Plane design parameter on the infrastructure and vice versa. To do so, formal dependency models will be set up according to the architecting activities of other work packages (WP1, WP2, WP3 and WP4). A dependency model allows predicting qualitatively and quantitatively the impacts of a decision made during the design process (i.e. a change) on the possible scenario identified for the infrastructure supporting its service.

- Change propagation model: Propose models for change propagation between Bee-Plane design/architecture and the airport.
- Change propagation qualification: Define appropriate propagation qualification indicators for sensitivity and immunity, but also on potential cost of change absorption.

Roles

- ISMEP will elaborate change propagation model and follow-up means.
- TECH will coordinate changes during project development with other partners (WP1 and WP8).

TASK 6.5 SUSTAINABILITY AND BUSINESS MODEL (M4-M30)

Lead: ISMEP – Contributors: TECH

Bee-Planes as any other planes will have environmental impacts; not only during their regular flights but also during their whole lifecycle. The lifecycle of a plane is generally estimated to be around 30 to 35 years. During these years, the aircraft passes through several maintenance visits and upgrading stages. Each of them will have impacts on the environment (spare parts for instance). From the other side, any adapted airport or newly designed and built airport will have impacts (economical, environmental and societal) that go far beyond the life of an airplane. This work package looks at the assessment of the Bee-Plane footprint and also the footprint of the changes that would be imposed by its integration within the airport. These footprints have to be gathered into one Bee-Plane-Airport footprint. Among others, the Carbon footprint is the most relevant sustainability indicator of these forecasted changes. Other indicators such as Environmental Footprint can be considered too. These Bee-Plane-Airport sustainability indicators have to designed and evaluated, comparing them with the traditional couple of Plane-Airport. This will allow extracting recommendations regarding the design and construction of Bee-Planes but also airports. In this case, the sustainability indicators will be evaluated for all of the main scenarios identified in the Task 6.2.

- Sustainability model: Identification of the Bee-Plane-Airport sustainability model including relevant measurement/assessment parameters. The national and international regulation rules and standards have to be taken into account here. This task will be done at the beginning of the project to provide outputs for design tasks where the sustainability and footprint should be considered as a general and overall requirement. To do so, the task will get use of the data collected in Task 6.1 and will seek for other relevant standards and techniques for the calculation of the Carbon and/or environmental footprint. These computing models should be therefore basically based on the state of the art of sustainability and durable development.
- Application of Sustainability model for the assessment of the scenarios: Once the other Work packages have identified and consolidated some scenarios for the future development and deployment of the Bee-Planes within airports, in this task we are going to assess the global sustainable impacts of each of these scenarios. This means that the previously sustainability models have to be applied to all of the scenarios.
- Business model: Identify and model several possible business models from three points of view: (i) companies operating upper aircraft only (ii) airlines that own only detachable fuselage and (iii) owners of complete Bee-Plane (aircraft and detachable fuselage). The goal is to identify strategies, either in term of number of Bee-Plane (aircraft and detachable fuselage), localisation, or of payment facilities (rent or buying). These strategies should enlighten the profitability, return on investment, and improvement levers for each of the three possible economic actors. These results could generate outputs necessary for WP1 in terms of number of available seats for passengers or space for freights.
  To make these analyses, a BPIM will be designed to offer different realistic scenarios to play with for infrastructure, business and the services offered or received by the main actors and stakeholders.

Roles

- ISMEP will formalize sustainability model and business model by using a BPIM.
- TECH will challenge key parameters according to market and environmental objectives.

TASK 6.6 RECOMMENDATIONS AND METHODOLOGY (M25 – M36)

Lead: ISMEP – Contributors: TECH

For each scenario considered/evaluated as feasible during task 6.3, recommendations and a methodology of scenario implementation will be proposed in this task. Different recommendations and methodology will be set up according to the concerned actor: the airport or the air company. Also, a set of planning and control measurements will be suggested to better control the implementation phase. For each scenario, the recommendations will be structured according to the main phases of the implementation project:

- Preparation phase: Definition of activities to be realised to prepare the implementation of each scenario.
- Implementation phase: Definition of activities to be realised to implement each scenario.
- Follow up phase: Definition of activities to be realised to follow up phase.
- Implementation methodology: Definition of whole implementation process for each scenario. It includes the definition of a risk management process that should be considered in each scenario implementation phase. Moreover, the planning and control measurements have to be defined to control the implementation project.

Roles

- ISMEP will provide recommendations, methodologies and will formalise planning and controls.
- TECH will challenge hypothesis with participants of SIG.

Deliverables

D6.1 – Heavy-trends scenarios and collected data-requirements (M12) **ISMEP**

- Collected data from airports authorities and air transportation authorities.
- Requirements book. This includes the engineered requirements (verification, requirements dependencies).
- Scenarios. The most realistic scenarios of integration of Bee-Plane in airport.
- Sustainability issues. Set of adapted sustainability measuring models (for carbon footprint or environmental burden) for Sustainability benchmark of the fine-tuned scenarios.

D6.2 – Change propagation, preliminary demonstrator and analysis (M24) **ISMEP**

- Change propagation mechanisms: conceptual and technical models for simulation of any change propagation between the Bee-Plane and the airport and more generally with the entire environment connected to the Bee-Plane concept.
- Change propagation demonstrator.
- Analysis preliminary results.

D6.3 – Benchmark of evaluated scenarios and demonstrator (M36) **ISMEP**

- Final results of the analysis of the integration of Bee-Planes in airports including scenarios' performance benchmark in terms of structural and functional dimension, sustainability dimension, business models.
- Demonstrator.

D6.4 – Bee-Plane implementation book (M36) **ISMEP**

- An integration project phases and guidelines with different scenarios of integration including the preliminary tasks to be performed; "Hows" and "Whens" where the operations to be conducted within the project have to be performed; a model for estimation of time duration and resource consumption for each scenario.

WP7

Work package number	**7**	Start date or starting event:			M2-M36			
Work package title	**Dissemination and exploitation**							
Participant number	1	2	3	4	**5**	6	7	8	9
Participant short name	TECH	ERT	LMS-SAM	TCD	**ARTTIC**	UNINA	MGEP	AED	ISMEP
P.M. per participant	6	0,5	0,5	1	**14**	1	0,5	0,5	0,5

Objectives

The objectives of WP7 are to:

- Communicate to the outside world in order to generate interest and prepare future phases of the Bee-Plane project:
  - Get recognition from the scientific community,
  - Make potential partners aware of the technology and its potential for the next phases.
- Set-up Special Interest Groups with aeronautics stakeholders, airport authorities, airport engineering companies and airlines able to:
  - Support the development of the Bee-Plane concept,
  - Identify potential showstoppers,
  - Identify Bee-Plane innovative components that could be used in more traditional aircraft.
- Contribute and participate to Aeronautics (e.g. Le Bourget Air Show 2015 & 2017) and EC (e.g. Aerodays) events.
- Prepare the exploitation and especially the next steps:
  - Draft a development and exploitation plan, including impact indicators,
  - Identify key technologies to be brought to TRL 3 and the way to make these developments.

Description of work

WP7 aims to prepare the next steps after the end of the project (how to move the technology forward) and support the dissemination of the project achievements through:

- Scientific and technical publications,
- Communication through different media (press, web, TV),
- Participation and animation of workshops or air shows (in particular Le Bourget Air Show),

- Courses and supporting projects for students from engineering schools.

These dissemination activities are of primary importance to maximise the impact of the project achievements and get the required visibility and contacts to prepare next steps.

In particular two Special Interest Groups related to "Airports & Airports' Supply Chain" and to Airlines will be set up to analyse their potential interest and potential resistance.

Preliminary contacts established with large industrial companies (AIRBUS IW and Safran Aircelle) will also be continued with the perspective of developing collaborations towards TRL3-TRL4.

IPR will be handled according to the Bee-Plane dedicated intellectual property rules. Main studies relate to the open source chapter of the Lesser Open Bee license 1.3 (www.bee-license.com). Results of studies will be displayed on the project wiki, accessible via Internet for future use and participants.

External resources to the project will also be used for this purpose:

- Support for TECH from regional agencies – notably Normandy AeroEspace (NAE - Agency supporting the aeronautic and space industry from Normandy) and SEINARI (Innovation agency from Normandy, research project number IRHN65) - in particular to prepare the development and business plan,
- Engineering projects to be performed by students from engineering schools (TCD, ISMEP, UNINA from the project plus ESTACA, ECP, INSA) with the support of professors and project participants.

Task 7.1 Project Dissemination (M2-M36)

Lead: TECH - Contributor: ARTTIC, ERT, TCD, MGEP, AED

- Prepare and update all along the project according to obtained results, a dissemination plan including a project indicator to measure the dissemination actions being performed (number of papers in the press and of publications ranked according to the media, media contacts, participation to conferences, visits on the web site, qualified contacts taken with stakeholders).
- Use www.bee-plane.com public website to allow public access to web-pages which will report project progress including the achievement of milestones understandable outside the Consortium and the access to public documents. Project follow-up information and main technical publication will be available on project public wiki.
- Disseminate results through papers in appropriate journals, at conferences and on company and EC web sites. Engineering journals and industry oriented events will be targeted including:
    - EC Aerodays (if one organised in 2017 or 2018),
    - On invitation: industry oriented events like Aero'Nov, Le Bourget Air Show in 2015 and 2017 (presence already confirmed for 2015 on the Normandy AeroEspace booth) and possibly Farnborough,
    - Several AIAA conferences on aeroacoustics, aerodynamics, etc. have been identified as promising events for dissemination.
- Develop communication material (flyers, posters, brochures) to support participation to events and conferences targeting different public levels such as general public, aeronautics stakeholders and scientific community.
- Set up and deliver courses and training plus engineering projects to be done outside the Bee-Plane project but contributing to strengthen TRL 2 achievement and initiate TRL3 studies. Projects with engineering schools have already been identified:
    - Aeronautical parameter studies by the engineering school Ecole Centrale de Paris,
    - Detailed equipment analysis and cabin internal layout studies by the engineering school ESTACA,
    - Certification Part 21 and Part 145 studies by the engineering school ESTACA,
    - Detailed mechanical studies on main landing gear by the engineering school Supmeca.
- Prepare a final public booklet presenting the project achievements and perspectives targeting potential partners for next steps. The booklet will be made available through the public web site and distributed during a final workshop.
- Organise and manage a public workshop to be held at M35 which will provide an overview of all project results and in particular ways forward and impact indicators.
- A reserve budget has been allocated for dissemination activities within the project and is currently included in ARTTIC budget. This budget will be used for the project events and for the production of dissemination material.

Roles:

- TECH will perform the main communication tasks.
- ARTTIC will coordinate the main events, provide methodologies and foster the network of contacts.
- The other partners will establish the technical guidelines to be communicated in join events.

TASK 7.2 PROJECT'S SUPPORT TO SPECIAL INTEREST GROUPS (SIG) (M4-M36)

Lead: TECH - Contributors: ARTTIC, ISMEP, TCD

- Make potential industrial or academic partners aware of Bee-Plane to develop relationship and prepare collaborations for next steps
  - ARTTIC will exploit its network of contacts in the aeronautic industry to promote the project achievements. The main target will be members from IMG4 (Euromart, EIMG and EqIMG), airports and airlines.
  - TECH will continue with the overall project communication using mainly aeronautical networks (Normandy AeroEspace, Astech, Groupement aéronautique de l'Association des Centraliens). TECH will also use its yearly newsletters to communicate overall results. Currently these newsletters reach more than 900 people (including more than 100 people directly involved in aeronautical innovation and R&D departments).
  - ISMEP will continue to contact the airports from the European countries (UK, IR, FR, DE, etc.) in order to make a very large survey of their needs and expectations. This survey will be public and a synthesis will be sent to all those collaborating airports. Statistics and results of the survey will be saved on the platform of the project and a short description of it will be published on the website of Bee-Plane.
  - TCD will utilise its role as a national contact point within the X-noise thematic network to promote and disseminate any potential benefits of the Bee-Plane as a technology for achieving the ACARE and Flight Path 2050 noise reduction goals. The X-noise network is also a valuable arena for identification of future industrial partners for exploitation of the Bee-Plane technology.
- Set up a Special Interest Group related to "**Airports**" to discuss the Bee-Plane concept with Airports, related supply chain, airports authorities and airport engineering companies and get elements to assess acceptance criteria and potential resistances. This group will be animated by ISMEP and ARTTIC with the support of the other partners, the work will be to:
  - Prepare documents to explain the concept and benefits for airports as well as potential difficulties (SWOT analysis open for discussion),
  - Communicate with airports and airport engineering companies that ISMEP, ARTTIC and TECH are already in contact with thanks to other projects,
  - Participate to conferences related to airport design such as Airport Development, Design & Engineering conference or Airport Planning, Design & Construction symposium,
  - Visit some airport and airport engineering companies,
  - In the context of this SIG, special workshops will be organised, in easy-to-reach cities such as Paris or London, mainly focused on the exposure of the synthesis of airports needs and requirements and challenges of the air industry in the context of Bee-Plane usage.
- Under the same principle, set up a Special Interest Group related to "**Airlines**" to discuss the Bee-Plane concept with Airlines and get elements to assess acceptance criteria and potential resistances. This group will also be animated by ISMEP and ARTTIC with the support of the other partners, the work will be:
  - Prepare documents to explain the concept and benefits for airlines, potential business models, as well as potential difficulties (SWOT analysis open for discussion),
  - Communicate with airlines ISMEP and ARTTIC are in contact through several projects,
  - Participate to conferences related to airline-related aircraft design conference or events attracting airlines (Le Bourget and possibly Farnborough or/and Berlin ILA Air Shows in 2016),
  - Visit airlines.

Roles:

- TECH will coordinate SIG.
- ARTTIC will provide support to the meeting organisation and communication activities.
- ISMEP and TCD will provide contacts and technical agenda.

TASK 7.3 PROJECT EXPLOITATION MANAGEMENT (M8-M36)

Lead: ARTTIC - Contributor: TECH - Support: All

- Monitor main Bee-Plane results in order to identify new innovative developments for patent or other protection means (drawing, copyright, etc.). The Bee-Plane Governing Board will be responsible for assessing innovative elements to protect, possibly with external support. The Governing Board with the moderation of ARTTIC will also negotiate property rights and patent costs according to the Bee-Plane consortium agreement.
- Address any IPR issue connected to the exploitation of the project results: licensing, further developments, etc. and collect Intellectual Property information (ownership, protection, access-rights, etc.) in a Bee-Plane Knowledge Register.
- Prepare impact indicators to be built from the project results and exchanges with stakeholders (SIGs)
  - Cost aspects on transporting passengers and freight with different Bee-Plane aircraft vs. different fuselages,
  - Cost of operating a Bee-Plane versus a traditional aircraft,
  - Acceleration of operations: fixed wing vs. Bee-Plane,
  - Airport capacities to compare fixed wing vs. Bee-Plane.
- Prepare a development and exploitation plan to bring the Bee-Plane Technology to TRL 3 – TRL 4 including identification of key developments and key partners:
  - Analyse the potential market needs for this type of aircraft at the 2040-2050 horizon,
  - Identify components of Bee-Plane that could be exploited on more traditional aircraft including landing gear, mixed engine configuration, locking system, etc.,
  - Provide a preliminary specification of the key components to be developed at TRL 3 – TRL 4 as well as a preliminary budget and planning,
  - Develop relationship with industrial and research organisations that could contribute to TRL 3 – TRL 4 studies and specify under which conditions this could be done,
  - Prepare a final SWOT analysis to select the best roads to successful exploitation.

Roles:

- ARTTIC will prepare exploitation plan and provide methodologies.
- TECH will establish project key messages and achievements.
- Other partners will provide technical results and network.

Deliverables

D7.1 – Bee-Plane public web site (M3) **TECH**

Project presentation and repository of all public documents and update of existing web site www.bee-plane.com.

D7.2 – Dissemination plan (M6) **ARTTIC**

Dissemination plan including the global dissemination strategy, first actions and a project indicator to measure the dissemination actions being performed (to be then updated every 6 months).

D7.3 – Portfolio of Publications (M36) **ARTTIC**

Portfolio of public documents, publications and media campaigns made by the project, an intermediary version will be prepared for the first project review.

D7.4 – Public booklet (M36) **ARTTIC**

Public booklet presenting project achievements and perspectives.

D7.5 – Development and exploitation plan (M36) **ARTTIC**

Plans for bringing the technology forward including conclusions on what has been achieved through the SIGs and the final SWOT analysis.

WP8

Work package number	**8**	Start date or starting event:			M1-M36			
Work package title	**Project management**							
Participant number	1	2	3	4	5	6	7	8	9
Participant short name	**TECH**	ERT	LMS-SAM	TCD	ARTTIC	UNINA	MGEP	AED	ISMEP

P.M. per participant	8	0	0	0	14	0	0	0	0

Objectives

The objectives of WP8 are to:

- Set-up the management infrastructure: project management and decision making committees, management procedures, quality plan, risk registers, project management tools, internal web site, etc.,
- Ensure the strategic management of the project,
- Make each partner focus on project five main objectives (innovation, aircraft, process, impacts, next steps),
- Provide financial and contractual management of the Consortium, including maintenance of the Consortium Agreement.

Description of work

In Bee-Plane the management tasks are shared between TECH and ARTTIC:

- TECH will ensure the strategic, financial and contractual management of the consortium.
- ARTTIC will ensure the day-to-day operational project management and provide the consortium with its project management experience, methods and tools.

Other management tasks are considered as technical management and are part of the work described in the WPs. The corresponding share of management tasks and responsibilities correspond with the terms of the H2020 Grant Agreement: the overall contractual responsibility is with the project coordinator TECH, who will in particular ensure the official interface between the consortium and the EC. The Project Office appointed by ARTTIC has the mission to provide project management support to the project coordinator and will therefore work under the direction of TECH. ARTTIC and TECH will work closely together and will make extensive use of web-based collaboration tools made available by ARTTIC. These will help support the creation of private web spaces and web conferencing. Furthermore, a specific section on the Bee-Plane private web space will be dedicated to management to ease sharing of management documents.

Further details can be found in section 3.2.

TASK 8.1 STRATEGIC MANAGEMENT AND FINANCIAL ADMINISTRATION (M1-M36)

Lead: TECH - Contributors: ART- Support: All

- Chair Bee-Plane General Assembly (BGA) meetings and ensure follow-through of decisions with the Bee-Plane Management Team (BMT).
- Supervise achievements and international state of the science and technology and propose evolution of the project's RTD orientations accordingly to the decision making BGA.
- Organise quality control: establish and benchmark project milestones, monitor the work plan and project progress, control of quality and consistency against technical and contractual aspects and make proposals for adjustments to the BGA as required.
- Administer the EC financial contribution, and distribute partner shares according to the rules defined in the Grant Agreement and the Consortium Agreement.
- Assure contract management for Grant Agreement and Consortium Agreement.

Roles:

- TECH will lead project according to technical, strategic and financial requirements
- ARTTIC will bring project tools, methodologies and guidelines.

TASK 8.2 CONSORTIUM MANAGEMENT (M1-M36)

Lead: ARTTIC Contributors: TECH -Support: All

- Organise project launch: establish procedures, project management methods and tools (project management plan, project and reporting templates, quality plan, risk register, indicators); organise project kick-off meeting.
- Organise and follow-up (planning, preparation, meeting logistics, minutes) periodic BGA and BMT meetings for progress review, strategy and decision making and conflict resolution.
- Coordinate internal and contractual periodic reporting, internal project reports (indicators and highlights) and EC and internal technical reviews.
- Co-ordinate timely production of deliverables and reports, and maintain project archive.

- Monitor the work being carried out, the results and the necessary changes to the work plan as a result of those findings, according to project milestones and indicators.
- Coordinate financial and administrative issues: establish and maintain financial records; coordinate financial statements submission by all project partners, follow-up of EC payments.
- Maintain contractual documents (Annexe 1 to the Grant Agreement, Consortium Agreement).
- Archive all proposal related documents.
- Provide a helpdesk to assist individual project partners on administrative issues and providing logistics support for the operations of WP Leaders.
- Provide access to (and administration of) ICT tools that facilitate the remote collaboration, communication and coordination, including a secured web-based private virtual workspace based on IBM Lotus QuickR technology, electronic archives, dedicated mailing lists, web- and/or teleconferencing services and a specific dedicated on line reporting tool to collect data for indicators and highlights.

Roles:

- ARTTIC will assure the daily project management and administration support.
- TECH will assure operational coordination among partners.

Deliverables

D8.1 Project Management Plan, Handbook on Management Procedures (M3) **ARTTIC**

This deliverable will encompass the methods, means and tools for the Bee-Plane consortium management It will complements other related documents (EC Grant Agreement and its annexes, the Consortium Agreement and the various EC guidelines), which, in case of conflict or uncertainty will prevail.

D8.2 – Progress Report – First period reporting (M18) **TECH**

This report will strictly follow the EC requirements for periodic reporting process. It will include both activity (at WP and partner level) and financial reporting of the period M1-M18.

D8.3 – Progress Report – Second period reporting (M36) **TECH**

This report will strictly follow the EC requirements for periodic reporting process. It will include both activity (at WP and partner level) and financial reporting of the period M19-M36.

D8.4 – Final Report– Final year reporting (M36) **TECH**

This report will strictly follow the EC requirements for reporting process and will include reporting data covering the full project duration.

3.1.4 List of work packages: Table 3.1b

#	WP Title	WP leader
WP1	**Concept specifications and aircraft design**	TECH
WP2	**Aerodynamic and acoustic studies**	TCD with UNINA
WP3	**Aerostructure**	AED with MGEP
WP4	**Equipment Design**	UNINA
WP5	**Mechanical simulation**	LMS-SAM
WP6	**Impacts on ground operations and processes**	ISMEP
WP7	**Dissemination and exploitation**	ARTTIC
WP8	**Project management**	TECH

3.1.5 List of major deliverables: Table 3.1c (sorted chronologically)

DEL. no.	Deliverable name	WP no.	Lead particip ant	Type	Dissemi -nation level	Deli-very date
D1.1	Aircraft initial overview	WP1	TECH	Report	PU	M1
D7.1	Bee-Plane public web site	WP7	TECH	Report	PU	M3

DEL. no.	Deliverable name	WP no.	Lead particip ant	Type	Dissemi -nation level	Deli-very date
D8.1	Project Management Plan, Handbook on Management Procedures	WP8	ART	Report	PU	M3
D3.1	Design criteria and procedures	WP3	AED	Report	PU	M4
D3.2	Basic Lines and ICD's	WP3	AED	Report	CO	M6
D4.1	Preliminary design of Equipment	WP4	UNINA	Report	PU	M6
D7.2	Dissemination plan	WP7	ART	Report	PU	M6
D1.2	Initial CDR1 report and aircraft conceptual overview	WP1	TECH	Report	PU	M12
D2.1	Initial aerodynamic and acoustic performance review	WP2	TCD	Report	PU	M12
D3.3	Preliminary structural concept and FEM	WP3	AED	Report & prototype	PU	M12
D4.2	Conceptual design of Equipment	WP4	UNINA	Report	PU	M12
D6.1	Heavy-trends scenarios and collected data-requirements	WP6	ISMEP	Report	PU	M12
D4.3	Advanced design of Equipment	WP4	UNINA	Report	PU	M18
D8.2	Progress Report – First period reporting	WP8	TECH	Report	PU	M18
D1.3	Intermediate CDR2 report and aircraft TRL2 description	WP1	TECH	Report	PU	M24
D2.2	Aerodynamic assessment of Bee-Plane design	WP2	UNINA	Report	PU	M24
D2.3	Advanced aerodynamic and acoustic performance review	WP2	TCD	Report	PU	M24
D3.4	Detailed CAD Mock-up and final FEM	WP3	AED	Report	CO	M24
D4.4	Detailed design of Equipment for TRL2	WP4	UNINA	Report	PU	M24
D5.1	Stress field at landing phase for initial design	WP5	LMS-SAM	Report	CO	M24
D5.3	Stress field at connection phase for initial design	WP5	LMS-SAM	Report	CO	M24
D6.2	Change propagation, preliminary demonstrator and analysis	WP6	ISMEP	Report	PU	M24
D2.4	Interior and Exterior noise assessment of Bee-Plane design	WP2	TCD	Report	PU	M30
D3.5	Assessment of Bee-Plane static and dynamic aeroelastic stability	WP3	UNINA	Report	PU	M30
D4.5	Improved design of Equipment	WP4	UNINA	Report	PU	M30
D5.2	Stress field at landing phase for final design	WP5	LMS-SAM	Report	CO	M31
D5.4	Stress field at connection phase for final design	WP5	LMS-SAM	Report	CO	M31
D5.5	Stress field at landing phase without landing gear	WP5	LMS-SAM	Report	CO	M31
D3.6	Stress Reports	WP3	AED	Report	CO	M32
D1.4	Final CDR3 report and aircraft final description	WP1	TECH	Report	PU	M36
D1.5	Final Innovation Summary	WP1	TECH	Report	PU	M36
D2.5	Final review of modifications for improved aerodynamic and acoustic performance	WP2	TCD	Report	PU	M36
D3.7	Detailed CAD drawings	WP3	AED	Report	PU	M36
D4.6	Final design of Equipment	WP4	UNINA	Report	CO	M36
D6.3	Benchmark of evaluated scenarios and demonstrator	WP6	ISMEP	Report & prototype	PU	M36
D6.4	Bee-Plane implementation book	WP6	ISMEP	Report	PU	M36
D7.3	Portfolio of Publications	WP7	ART	Report	PU	M36
D7.4	Public booklet	WP7	ART	Report	PU	M36
D7.5	Development and exploitation plan	WP7	ART	Report	PU	M36
D8.3	Progress Report – Second period reporting	WP8	TECH	Report	PU	M36
D8.4	Final Report– Final year reporting	WP8	TECH	Report	PU	M36

3.1.6 PERT chart

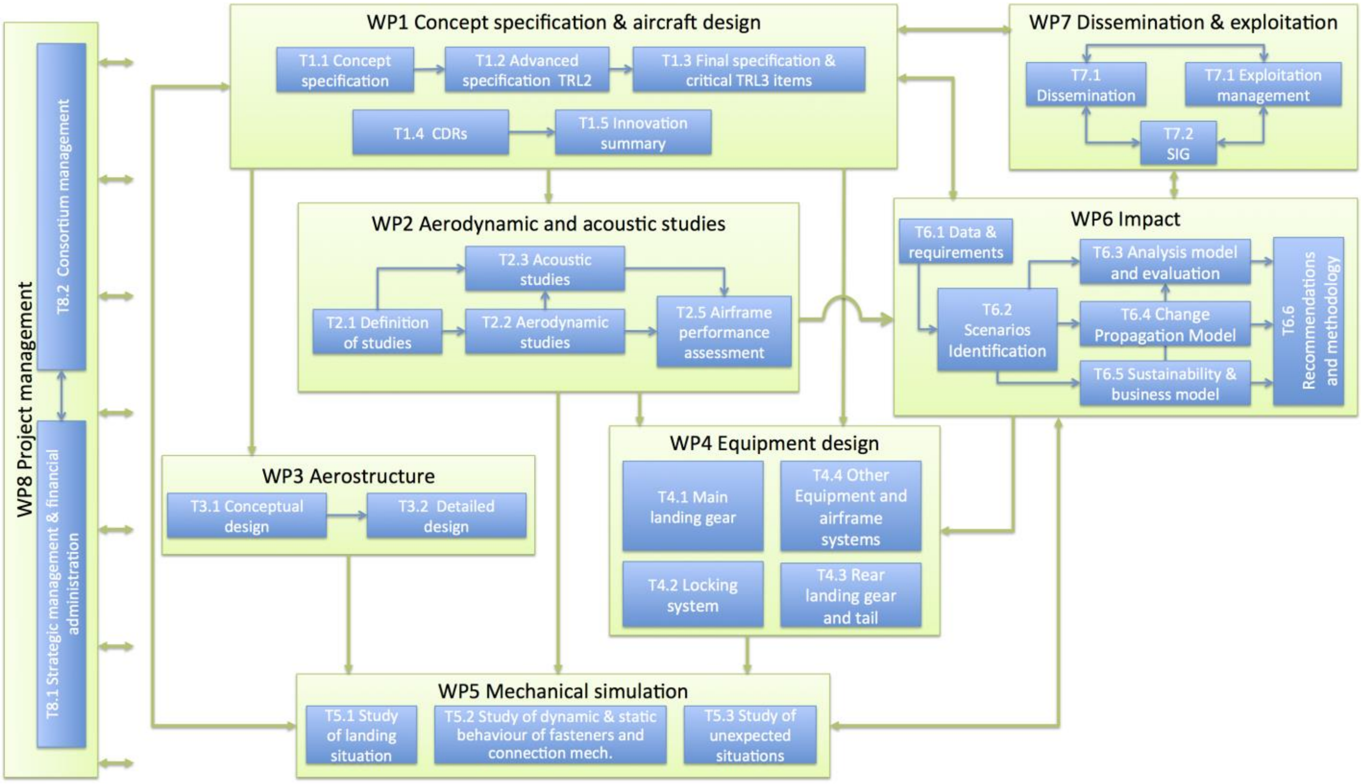

Figure 30: PERT diagram

3.2 Management structure and procedures

The Bee-Plane management structure and procedures are based on the experience in previous R&I collaboration projects and methods and tools that have proved efficient. The Bee-Plane partners will sign a consortium agreement that is based on the H2020 DESCA model directly inspired from the FP7 version and used successfully in many FP7 projects. All partners decided to use this model when submitting this proposal and have already agreed on the broad management principles, including project governance and decision making, management of project finances, and IPR and dissemination rules. They will sign it before the project starts.

The Bee-Plane management structure is designed to reach the following objectives:

- Ensure timely and qualitative achievement of the project objectives, including coordination of activities, risk mitigation, recovery plans and quality control,
- Provide decision making and conflict resolution mechanisms,
- Provide timely and efficient financial and administrative co-ordination of the project,
- Support the activities that need a strong coordination and in particular aligning dissemination, innovation management and preparation for exploitation activities with the progress of the work and achievements.

3.2.1 Bee-Plane organisational structure

The corresponding DESCA organisational structure will reconcile the need for result driven management and fulfilment of contractual obligations with the required flexibility to adapt the R&I strategy to the constantly evolving international scientific/technical (S/T) and market context.

The organisational structure will be suitable for a project of the size and complexity of Bee-Plane with 9 partners and 8 work packages. The same structure has been successfully applied in several Level 1 Aeronautics projects of FP7. The Bee-Plane organisational structure will have different levels to distinguish decision making from operational management, central from local coordination needs, and needs for innovation management, conflict resolution and scientific/strategic advice.

The following figure represents the governance structure and the accountability between the different bodies:

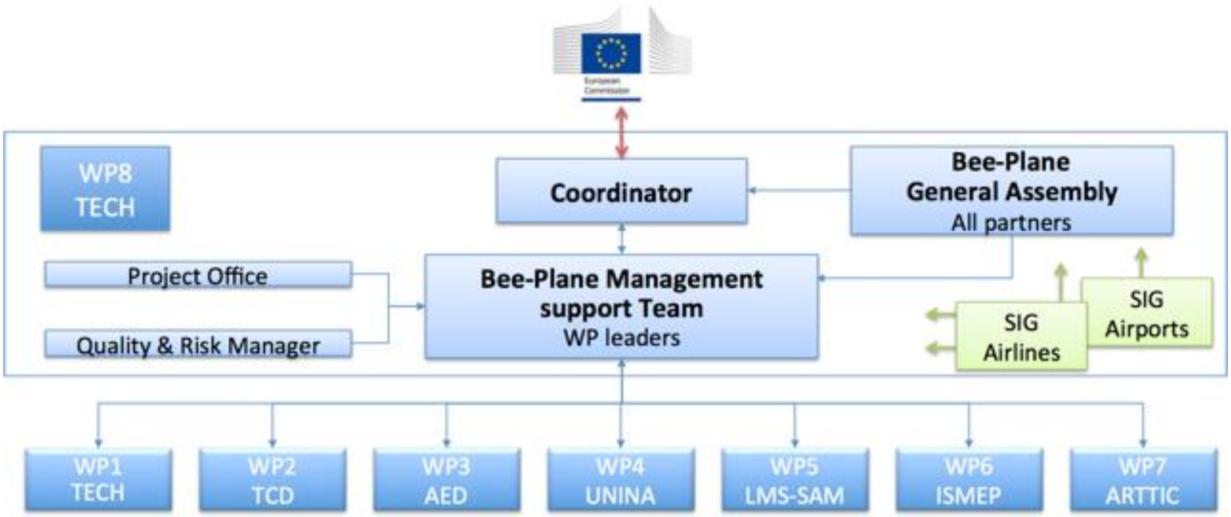

Figure 31: Bee-Plane organisational structure

MAIN BODIES

The management organisation will rely on two main bodies to distinguish decision making from operational management:

- A **Bee-Plane General Assembly** (BGA) – the formal decision making body of the project for any issue concerning the proper operation of the Consortium,
- A **Bee-Plane Management Support Team** (BMT) – the operational body in charge of preparing and implementing decisions of the BGA and in charge of the technical coordination of the project.

A **Project Director** from TECH, Xavier Dutertre, and a **Project Office** provided by ARTTIC will support the BGA and the BMT. ARTTIC will also provide a **Quality & Risk Manager** in charge of the follow up of the quality plans and regular updates of a risk register.

In addition, as part of the Dissemination and exploitation WP, two Special Interest Groups related to “Airports & Airports’ Supply Chain” and to “Airlines” to support the innovation process for the Bee-Plane technologies (details in 2.2.3) will be set up and supported by the Project Office and the BMT.

DECISION MAKING: BGA (BEE-PLANE GENERAL ASSEMBLY)

The BGA will take any and all decisions required for the proper conduct of the project. Any partner might invoke the arbitration of the BGA whenever decisions appear contrary to the partner interests. Decisions within the BGA will be taken upon 2/3 majority, each partner having one vote.

The BGA is a formal body that will meet usually at the same time than the project reviews. All decisions of the BGA will be taken remotely through web conferences and using an electronic voting system. Its composition and the rules of proceedings are those of the H2020 DESCA Consortium Agreement model adapted to the specific Bee-Plane context. The non-limited list of matters to be acted upon by the BGA may include:

- Define the strategic orientation of the project especially regarding impact, IPRs and exploitation,
- Manage changes in the Consortium membership and non-performing partners including notice served to defaulting partners,
- Propose and approve changes in the work plan, work sharing, important resource (re)allocations and budget and any consequent amendments to the contract with the Commission,
- Manage the decision-making process to distribute payments to the partners, in accordance with the conditions specified in the Consortium Agreement.

PROJECT OPERATIONAL MANAGEMENT: BMT (BEE-PLANE MANAGEMENT TEAM)

The BMT is composed of the WP leaders. The BMT is in charge of the daily project operations:

- Implement the strategic orientations decided by the BGA and the decisions of the BGA,
- Prepare the programme of activities, including the budget and the allocations,
- Monitor the activities, including problem solving, quality

WP	WP Leader	BMT member
WP1	Xavier Dutertre	TECH
WP2	John Kennedy	TCD
WP3	Igor Otero-Martin	AED
WP4	Francesco Amoroso	UNINA

assurance, production of deliverables and achievement of milestones,
- Prepare progress reports on the state of advancement of the project,
- Manage contractual and administrative aspects of the project.

WP5	Chafi Kaici	LMS Samtech
WP6	Marc Zolghadri	ISMEP
WP7	Laura Maroto	ARTTIC
WP8	Xavier Dutertre	TECH

Decisions within the BMT will be taken by simple majority vote. In practice, the BMT will always tend to agree on a consensus basis. In case of major problems, the BMT will propose decisions to be taken by the BGA. Specific operational procedures (representation, meeting preparation, organisation, minutes, voting, quorum, and veto rules, etc.) will be followed as specified in the Consortium Agreement.

The BMT chairperson is the Project Director. He will monitor the project technical implementation carried out by the WPs. He will manage the project on administrative and financial aspects with the help of the Project Office.

The BMT will meet at least quarterly. Whenever possible, electronic means will be used instead of physical meetings. The review of project progress, including status of deliverables and milestones and risk management (see below) will be standard topics of the BMT agenda.

WP MANAGEMENT

The WP level S/T coordination will be ensured by the WP Leaders. They will be in contact with the task leaders and partners involved in the WP. Depending on the size and complexity of the WP and the on-going activities, regular coordination meetings will be organised at the WP or at the Task and WP level. The WP Leaders will report to the BTM about WP progress, problems encountered and risks identified and ensure follow-through of BTM decision at the WP level. They will also ensure that the information required for the update of indicators and Periodic Progress Reports regarding the WP will be provided in time and meet the expected quality.

3.2.2 Bee-Plane operational bodies

THE COORDINATOR

Xavier Dutertre, president of TECH, will be in charge of the overall technical and impact supervision and representation of the project. X. Dutertre, who is at the origin of the Bee-Plane concept, is and has been involved in several collaborative projects and has multiple experiences in managing complex industrial projects. Within TECH, a dedicated project manager will lead technical development, drive planning, coordinate tasks and check deliverables. The coordinator will be the intermediary between the consortium partners and the European Commission. He will perform all tasks assigned to him as described in the Grant Agreement and the Consortium Agreement.

THE PROJECT OFFICE

The coordinator will be assisted by ARTTIC that will also provide assistance to the BMT for the day-to-day operational management and project administration tasks through a Project Office. ARTTIC has an extensive experience of the management of projects in aeronautics (25 projects in FP7 in this field, including 13 L1) that will be exploited in Bee-Plane. The Project Office will be staffed with personnel experienced in the management of international R&I collaboration projects and related administrative, logistics, financial, quality management, legal/IPR, information dissemination, and technical aspects. The Project Office will work in close cooperation with the Coordinator. The share of responsibilities and tasks between ARTTIC and TECH are well reflected in the tasks definitions of work package WP8. The Project Office will take care of the operational management, the various day-to-day management and coordination tasks as described in WP8.

QUALITY & RISK MANAGER

A Quality & Risk Manager will be appointed by ARTTIC to establish and validate quality control procedures, risk management procedures and risk register management. The Quality & Risk Manager will take care of the daily monitoring of quality control and risk register follow-up.

3.2.3 Conflict resolution

Conflict resolution is fully addressed by this organisational structure:

- Conflicts will first of all be addressed by the search of consensual but effective solutions at the smallest level of subsidiarity – the directly concerned parties.

- Should that fail, conflicts will then be escalated to the BMT level, which will make a recommendation to the conflicting parties. This recommendation can include the nomination of a mediator, or an arbitration process, which can then be decided upon by the BGA.
- Should this second level of conflict resolution equally fail, the BGA will proceed to the resolution of the matter by strictly applying the clauses of the Consortium Agreement, which will include provisions for dealing with the matters that cannot be simply resolved by mutual agreement.

Except if the Project Office or the Coordinating Partner is party to the conflict, the Project Office will manage the conflict resolution process at the aforementioned levels under the authority of the Coordinating partner. Otherwise the BGA will nominate a 3rd party to manage the resolution process.

3.2.4 Bee-Plane management plan

The main project procedures and ways of working will be documented through a series of short documents ("Bee-Plane project management handbooks") covering the main project management issues, including quality and risk management. In particular, to assess and validate the project output, Bee-Plane will implement:

- **Internal Technical Reviews (ITR)** to which most project milestones will be attached. In these reviews that will take place every six months, each organisation will involve his key experts to perform this assessment. Output from these technical reviews will be documented in a formal report including acceptance or not plus recommendations from the participants. Such an approach corresponds to existing internal industrial procedures that have proven their effectiveness over the years.
- **Critical Design Reviews (CDR)** every year to formalized main achievements made by each partners. Critical design reviews are part of the conception loop, allowing a regular update of the concept and the configuration.
- A **Quality Review (QR)** process for each deliverable to check if the document and corresponding technical output match the initial requirements, correspond to the level of quality expected by the participants and provide an exploitable documentation.
- A **risk management plan** to be described through a **risk register** to follow the major potential risks with mitigation plans and recovery plans whenever needed (see below for a first list of risks to be considered). The risk register will be reviewed and updated at each NMC meeting or teleconference.
- A **set of indicators** to follow the progress of the work from a management perspective (deliverables approved, milestones achieved, person-months and budget consumption, Gantt, risk indicators, action list and technical indicators reflecting progress towards objectives).

3.2.5 IPR and innovation management

The partners will share the access to IP generated during the project based on the fundamental IPR rules defined in the H2020 Grant Agreement that will be completed with the Lesser Open Bee License to be used by the partners for IPRs and that will be signed by the participants before the signature of the Grant Agreement.

The **Bee-Plane Management Team** will perform the following tasks:

- **Bee-Plane knowledge portfolio management and exploitation and dissemination plans**: the participants through the work packages will generate IPRs related to new foreground. Participants involved in the project but possibly not directly in the same work packages will need access to this foreground to perform their own research or for use. The Innovation team will:
  - Collect information on the foreground generated in a **Bee-Plane Knowledge Portfolio,**
  - Agree, with their owners, the standard access conditions within the project and for exploitation,
  - Verify that all IPR aspects are contributing to the Bee-Plane exploitation and dissemination plans and will not create showstoppers or issues in exploitation,
  - Maintain the Bee-Plane Knowledge Portfolio according to licenses exchanged and protection made.

  This Bee-Plane Knowledge Portfolio will be a key tool to support a smooth collaboration between organisations that may have different exploitation interests. The Knowledge Portfolio will also be the means to support dissemination and future use of the project results. It will take into account existing IPR among partners, as:

  - TCD has a number of in house codes for aircraft noise assessment that have been developed through interaction with previous European projects and graduate research programmes. There is the potential to further develop these codes in the Bee-Plane project. In general these codes have not been developed for commercial implementation and TCD reserves the rights over this material.

  - LMS-SAM already possesses mechanical simulation computerized tools. Results of calculation will be shared among partners and within project deliverables. LMS-SAM owns rights on existing source codes of computerized tools.
- **Knowledge protection**: The Innovation Team will:
  - Mostly refer to the open source paragraph (#2) of the lesser open license 1.3 (see www.bee-license.com) for calculation results and design tasks,
  - Approve associated work with dedicated licence mostly for tools and methods existing before the project,
  - Moderate and propose solutions in case of co-ownership between different participants,
  - Advice and support protection when required (patent, copyright, etc.),
  - Identify background requiring specific accesses: collect, update and maintain the list of the major background required to implement Bee-Plane.
- **Publications**: the Innovation Team will ensure that the policy regarding publications as defined in the Consortium Agreement (currently fully following the Grant Agreement principles) and implemented by the project is respected by all project participants. All publications will be subject to the Bee-Plane BGA approval.
- **Consortium Agreement maintenance and evolution:** the Innovation Team will maintain the Consortium Agreement and prepare corresponding decisions of the Bee-Plane BGA, in particular, related to the modifications of the background, termination of participation and entrance of participants.
- Access rights and possible conflict resolution: the Innovation Team will:
  - Handle and moderate discussions related to accessing the background and foreground to be granted according to the needed information to carry out the tasks involved in the work packages,
  - More generally, moderate and propose fair solutions to any possible conflict related to IPRs.

The Project Office will support these activities and will take care of all logistics and drafting of documents.

3.2.6 Main project milestones

Milestone number	Milestone name	Related WP	Estimated date	Means of verification
M1	Consortium agreement signed and kick-off meeting held	WP8	M1	Formal approval of project organisation and plans by the BGA
M2	Secured web-based private virtual workspace available	WP8	M2	Site on line, all participants having a login and password
M3	Le Bourget Air Show 2015	WP7	M4	Effective presence on a Bee-Plane booth
M4	Preliminary milestone	WP3	M6	Deliverable D3.1.2 published Basic lines and ICD's
M5	Conceptual milestone, CDR1	WP1	M12	Deliverable D1.2 published Aircraft conceptual overview
M6	Advanced milestone	WP4	M18	Deliverable D4.3 published Advanced design of equipment
M7	First periodic review held	WP8	M19	Formal approval of reports and deliverable by EC and reviewers
M8	Detailed milestone, CDR2	WP5	M24	Deliverable D5.3 published Stress field at connection phase for initial design
M9	Le Bourget Air Show 2017	WP7	M28	Effective presence on a Bee-Plane booth
M10	Improved milestone	WP5	M31	Deliverable D5.4 published Stress field at connection phase for final design
M11	Final review held	WP8	M36	Formal approval of reports and deliverable by EC and reviewers

In addition to these main project milestones, each WP will specify technical milestones on a regular basis to check the project progress and to implement corrections when needed.

3.2.7 Critical risks for implementation

To manage these risks, a **risk register** will be set up to:

- Identify the main risks, the potential causes and their impact on the objectives, the resources, the budget and the planning,
- Prepare mitigation plans to reduce the risks to occur and recovery plans in case of any problem,
- List key indicators to follow the risk and get early "red light" whenever required.

The following table contains the major identified risks. These risks are considered as "high" or "medium" risks". "Low risks" are not detailed here but will be followed at work package or task level.

Description of risk	WP	Proposed risk-mitigation measures
High risks		
Difficulties to reach technical targets (fuel burn reduction, cost reduction, etc.) Consequences: project stops at TRL2	WP1	The recurring CDR workshop will allow a regular evaluation of the difficulties, offering possible other roads to the development. Failure cases (engines and main equipment) are included in all WPs in order to focus on realistic and operational constrains. One task of WP5 will focus on mechanical simulation when main landing is not functioning correctly
Cost and weight of the three engines configuration Consequences: configuration to be change to a single type of engines	WP1	Acquisition cost and weight are taken into account in the TRL1 output. The main issue might be maintenance and for that different configurations will be evaluated with enough flexibility to be able to make the final selection of the engines against a cost analysis. Low cost solution could be provided using very well-known engines (e.g. CFM56 and PW150A) or their successors
Development of the complex specifications of an entire medium range aircraft could generate delays especially if too many details are given on unnecessary sub-tasks Consequences: project's delays	WP1	Mitigation plan includes a conception loop involving each partner in order to align project targets, technical objectives, studies and results all over partners Planning of tasks and deliverables will be carefully followed all along the project to avoid time spread. Regular discussion and workshops with partners on intermediate tasks and results will be conducted
Insufficient data available from manufacturers for embedded engine noise studies (fan noise interior and exterior). Studies are limited to a representative engine either embedded or a traditional design placed at the engine location Consequences: poor analysis	WP2	Fan noise studies are planned for the second year of the project allowing time for data gathering to occur from likely engine manufacturers. Numerous partners have close links with aerospace industry with potential access to this information
Delay in data collection Consequences: delay in deliveries	WP5	Anticipate by a parameterized model ready to be quickly modified
Difficulties to set up reliable exploitation plans and more particularly next developments to fulfil TRL 3-TRL 4 Consequence: exploitation compromised	WP7	Next steps will require investment certainly difficult to get The first mitigation is project dissemination focussed on making the aeronautics community aware of the potential benefits and feasibility of the concept to attract new partners: large research organisations and then the industrial stakeholders. The second mitigation will be to use Bee-Plane project as a Concept-plane and identify clear benefit to future partners: develop exploitation paths limited to some parts of the concept exploitable in more traditional aircraft as done in other initiatives (e.g. the NACRE integrated project in FP6). Dissemination includes an "innovation summary" task in WP1 to focus on new models, methods and innovations usable in other future aircraft projects.
Medium risks		
Difficulties to reach structure optimum weight according to the specific detachable configuration Consequence: targeted fuel	WP3	AED will provide its experience in the analysis and design of aeronautical structures. Analysis will take into account that detachable fuselage is pressurised as conventional aircraft and that upper aircraft may not be pressurised. Loading entry point between aircraft and detachable fuselage will also be considered in detailed relation with WP3 and WP5

Description of risk	WP	Proposed risk-mitigation measures
consumption not reached		
Potential showstopper of tail dragger configuration on a medium range aircraft Consequence: additionnal weight for additional front gears	WP4	Project will benefit from UNINA – Aerospace Engineering department - experience in the design of innovative aeronautical structures. Detailed feasibility analysis will take into account loads on main and rear landing gears, position of gravity centre linked with braking forces (including reverse of turbo propellers) during short landings or aborted take-off
Low-level Airports' data and requirements collection. Consequences: scenarios design will be in difficulty	WP6	Lots of available reference books and reports could be properly combined with the low-level obtained data and requirements To overcome this, the Bee-Plane consortium has already in contact with airports (Lyon, Clermont-Ferrand, Bordeaux-Merignac and Bergerac in France and Birmingham in the UK). All these actors agreed to give required data that would allow the design of the main scenarios. Moreover, the creation of the Special Interest Group from the beginning of the project is a solution to this risk
Lack of ground data related to the reluctance of airports and air companies to share their data. Consequences: non-adequacy of scenarios	WP6	The close interaction with the air industry actors will be a clear guarantee to define the most relevant scenarios for the project
Low demonstrator and deliveries maturity. Consequences: The computation of the analysis results and simulation can be more difficult	WP6	1) The maturity of the demonstrator should not be taken as a necessary condition for the success of the WP. Collection of results from various scientific tools (Matlab, Bayesia, etc.) should limit any negative consequence of the demonstrator achievement 2) The use of specialized tools for airport planning and control, and simulation can be regarded as a serious mitigation approach to limit the non-mature level of the demonstrator
Scaling techniques difficulties. Consequences: The analysis cannot be performed as planned according to several scales	WP6	The analyses are planned to be able to run for various scales of models (structural, functional, etc.). Even if the scaling techniques are not mature enough, research efforts will be focused on them from the beginning of the project
Difficulties to get access to stakeholders (airports, airlines and industry) to prepare the future Consequence: Unreliable exploitation plans	WP7	Participants do have contacts and working relationship in projects with all the major key European stakeholders, some already mentioned an interest for the concept. The approach to avoid rejection and to open the right doors will be set up: • With existing contacts relying on their perception of the technology, the business, the potential benefits and showstoppers, • Through participation to major events, • Through media and publication campaigns, • Though impact criteria and business plans including SIGs feedback
Lack of resources, poor control of the work, poor coordination Consequences: Delays and budget issues	WP8	Regular contact with participants through the BMT and BGA Management process (including indicators, milestones and risk register) as described in the management guidelines based on hundreds of successful projects Basic project management based on two milestone per year and an annual CDR (Critical design Review)

3.3 Consortium as a whole

The Bee-Plane consortium consists of 9 partners from 5 countries:

- 3 SMEs: TECH (FR), ERT (IT) and ARTTIC (FR),
- 4 Universities: TCD (IE), MGEP (ES), ISMEP (FR) and UNINA (IT),
- 2 industrial companies: LMS-SAM (BE) and AED (ES).

Together they bring the necessary experience and resources to explore the various challenges of this project:

breakthrough concept ideas, design capabilities, simulation and evaluation capabilities and management/ dissemination experience to ensure the success of the project and its exploitation.

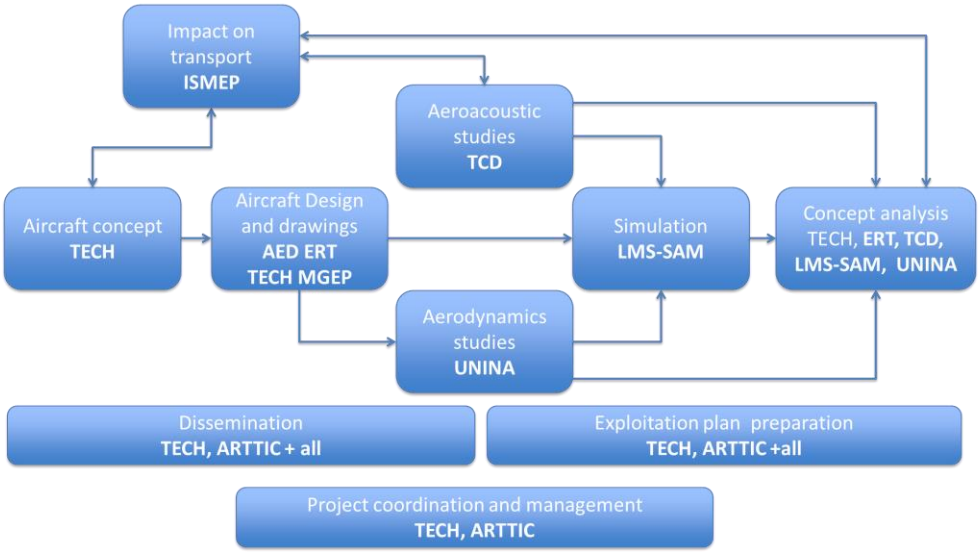

Figure 32: Bee-Plane overview of the consortium

A key feature of the consortium is that critical design tasks (aircraft and equipment) will be conducted by SMEs (TECH, ERT), who have flexibility and open minded ideas. Project will benefit from industrials experience on structural and mechanical simulation. Successfully achieving the project objectives at TRL 2 will constitute the key arguments to convince larger organisations (as a large aircraft manufacturer) to join consortium at TRL 3. This approach was also taken during the development of the project to TRL 1 and successfully leads to the current consortium. Regular communication with larger organisations was achieved in order to validate technical guidelines and aeronautical configurations.

Participant	Background / expertise / skills	Role / main contribution
SMEs		
TECH	At the origin of this breakthrough aircraft architecture, has already conducted the TRL 1 studies	Coordinator, WP1 and WP8 leader Providing the scientific, technical and economic coordination of the project Focussing on providing specifications and initiating conception loops using results made by all the partners Organisation and exploitation of regular Critical Design Reviews (CDR) to develop the concept towards TRL 2
ERT	Specialist of structural dynamics, structural modelling as well as environmental and industrial acoustics and noise control	ERT will be a contributor in WP2 and WP4, respectively on acoustic studies and mechanical design Focussing on providing expertise in the fields of acoustic and vibration, structural dynamics, systems' control and experimental characterization of integrated technologies for Bee-Plane
ARTTIC	R&D strategy consulting, proposal development, project management and dissemination/exploitation (WP7 and 8), in particular through involvement in 80 FP7 projects	WP7 leader Supporting the management and dissemination tasks of the project. In particular, ARTTIC will exploit its network of contacts to help setting up the two SIGs and getting in contact with the European aeronautic industry at large
Industry		
AED	Business unit of Engineering of the AERNNOVA AEROSPACE GROUP, specialist of design, development and certification of large metallic and composite aero-structures	WP3 leader Performing structural analysis and verifying the final design, aiming at achieving low weight structures Selecting optimal material according to wings and fuselage constraints
LMS-SAM	Part of the LMS Intl group, itself part of SIEMENS, LMS-SAM develops and markets the general purpose FEA code	WP5 leader Focussing on simulation and computation of mechanical behaviour of the plane in different situations (landing with

Participant	Background / expertise / skills	Role / main contribution
	SAMCEF and the Model-Based Engineering Framework CAESAM. LMS SAM is already well established and known in the aerospace market	full passengers, connection between plane and detachable fuselage, landing in extreme situation) in order to define maximum stresses values and capacity of plane to resist at these scenarios. Computations will be done with SAMCEF which is able to compute following analyses: linear and non-linear static, linear and non-linear dynamics, mechanisms and kinematics LMS-SAM contribution to Bee-Plane project will reinforce Bee-Plane project future partnership opportunities and LMS innovation plan
Academic		
TCD	Expertise of research for over 30 years on modelling and analysis of flow/structure interaction including aero acoustics and vibro acoustics. TCD has participated to numerous EU projects in this area, mostly recently as coordinator of Clean Sky projects WENEMOR, ALLEGRA and ARTIC	WP2 leader Conducting a full noise assessment of the Bee-Plane, investigating both interior and exterior noise problems. This will exploit the wide range of expertise which TCD has demonstrated though involvement in previous EU research projects on the various aircraft noise components
UNINA	Expertise in structural dynamics, aero elasticity, vibro-acoustics, active control of noise and vibration, smart structures/systems and structural health monitoring, aerodynamics, space systems, flight mechanics, microgravity and remote sensing	WP4 leader. Performing aerodynamic analysis Overviewing and verifying the overall design, aiming at achieving low weight structures, in compliance with aeronautical standards. UNINA will finance contracts for fixed-term researcher, PhD or Temporary Research associate having as its object the study of Bee-Plane
ISMEP	Knowledge and expertise in terms of operations management, modelling and simulation of goods/service production, and applied mathematics Experience on Bee-Plane to conduct TRL 1 studies	WP6 leader Studying the impacts of the integration of Bee-Planes in airports Preparing the specification book for a successful Bee-Plane integration within the airports (adapted or dedicated) Assessing, qualifying and quantifying the impacts of Bee-Plane on the airport and other supply chain members related to the airport
MGEP	Expertise in structural modelling, mechanical simulations and light weight structures	Design of multi-material lightweight structures: metallic and composite parts taking into account their interactions Establishing partnerships with European institutions in strategic and technologically advanced sectors such as the aeronautical sector Developing new research topics and exchanging students and researchers with other institution

3.4 Resources to be committed

3.4.1 Summary of staff effort: Table 3.4a

#	Partic.	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	Total PM
1	TECH	32,00	4,00	2,00	5,00	3,00	7,00	6,00	8,00	**67,00**
2	ERT	0,5	3,00	2,00	26,00	0	0	0,50	0	**32,00**
3	LMS-SAM	0,5	0	0	0	36,50	0	0,50	0	**37,50**
4	TCD	0,5	54,50	2,00	0	0	0	1,00	0	**58,00**
5	ARTTIC	0	0	0	0	0	0	14,00	14,00	**28,00**
6	UNINA	0,5	20,50	0	36	0	0	1,00	0	**58,00**
7	MGEP	0,5	0	56,70	0	0	0	0,50	0	**57,70**
8	AED	0,5	0	91,90	0	0	0	0,50	0	**92,90**
9	ISMEP	0,5	0	0	0	0	62,00	0,50	0	**63,00**
	Total	**35,50**	**82,00**	**154,60**	**67,00**	**39,50**	**69,00**	**24,50**	**22,00**	**494,10**

3.4.2 Other direct cost items: Table 3.4b

1.TECH	Cost (€)	Justification
Travel	10 800€	Attendance at project meetings and dissemination events
Equipment	1 000€	Software licences and PCs
Other goods & services	20 000€	Le Bourget Air Show 2015 and 2017 booth
Other goods & services	2 000€	Audit costs
Subcontracting	10 000 €	Display mock-up for Le Bourget Air Show in 2015 (as described in §4.2.1)
Subcontracting	10 000 €	Display mock-up for Le Bourget Air Show in 2017 (as described in §4.2.1)
Total	53 800€	

2.ERT	Cost (€)	Justification
Travel	5 000€	Attendance at project meetings and dissemination events
Equipment	5 000€	PC, software license
Other goods & services	7 000€	WT bee-plane model
Total	17 000€	

3.LMS-SAM	Cost (€)	Justification
Travel	13 500 €	Attendance at project meetings and dissemination events
Other goods & services	2 000€	Audit costs
Total	15 500 €	

4.TCD	Cost (€)	Justification
Travel	12 000€	Attendance at project meetings and dissemination events
Equipment	3 000€	Software licences and PCs
Total	15 000€	

5.ARTTIC	Cost (€)	Justification
Travel	6 000€	Traveling for 15 trips (one or two persons, 400€ on the average)
Other goods & services	43 000€	Logistics for 7 general meetings (room, catering, social, event): kick-off, M6, M12, M18, M24, M30, M36. Workshop organisation: flyer, meeting room; catering, etc. Printing brochure, poster, and document for dissemination.
	2 000€	Audit Costs
Total	51 000€	

6.UNINA	Cost (€)	Justification
Travel	9 000€	Attendance at project meetings and dissemination events
Equipment	10 000€	PC, software license
Other goods & services	2 000 €	Audit Costs
Total	21 000€	

7.MGEP	Cost (€)	Justification
Travel	9 000€	Attendance at project meetings and dissemination events
Other goods & services	2 000 €	Audit Costs
Total	11 000€	

8.AED	Cost (€)	Justification
Travel	9 000€	Attendance at project meetings and dissemination events
Other goods & services	3 000€	Audit Costs
Total	12 000€	

9.ISMEP	Cost (€)	Justification
Travel	13 600€	Attendance at project meetings and dissemination events
Other goods & services	2 000 €	Audit Costs
Subcontracting	30 000€	Tasks to prepare recommendations for the integration of Bee-Plane in the airports support from an architect company (as described in § 4.2.2)
Support to third parties	27 330€	Resources from Paris 8 University (as described in § 4.2.2)
Total	72 930€	