COST Action proposal — stratospheric vehicle design

Draft Technical Annex · for partner comment

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1. EXCELLENCE IN S&T AND NETWORKING

1A. Main challenge

Persistent flight in the lower stratosphere has moved from concept to demonstration. Uncrewed, solar-powered platforms have sustained flight at altitudes between 18 and 22 km for periods extending from days to months, and the applications that motivate them are civil, immediate and economically significant. What has not been established is a dependable, reproducible engineering basis for designing such vehicles. Demonstrators have flown; a design discipline has not yet formed around them.

The difficulty is that the design problem at these altitudes resembles neither conventional aviation nor spaceflight. Air density is approximately seven per cent of its sea-level value, so lift must be produced by very large wing areas carried by very little mass. The resulting structures reach slenderness and flexibility far outside conventional experience, deflecting so substantially in ordinary flight that linear aeroelastic theory ceases to describe them and geometric non-linearity governs both static shape and dynamic response. Wing and propeller sections operate at Reynolds numbers of order 100 000, one to two orders of magnitude below those of transport aircraft, where established design correlations lose validity and laminar–turbulent transition dominates performance. Temperatures near and below −60 °C combine with near-vacuum convection and large diurnal swings to hold batteries, actuators and polymer-based structures close to their limits. Ultraviolet and particle exposure degrades thin films and composites over the months for which such a vehicle must remain aloft, so design is governed by durability, not by discrete load cases. And each of these constraints feeds a single energy balance that must close over a full twenty-four-hour cycle: energy collected during the day must carry the vehicle through the night, with mass, area, efficiency and atmospheric variability entering the same equation. A modest error in any one discipline moves a design from feasible to impossible.

The challenge is timely for three converging reasons. First, the enabling component technologies — photovoltaic conversion efficiency, battery energy density, ultra-light composites and films — have only recently reached levels at which flight measured in months, not days, becomes a serious engineering proposition. The governing question has consequently shifted from whether such vehicles can fly to how they can be designed dependably and repeatedly: a question about method, not demonstration. Second, the regulatory framework for operation at these altitudes is being formed now, and decisions taken over the next few years will set the conditions of access for a generation; a technical evidence base assembled afterwards will have little influence upon them. Third, and most consequential for the discipline itself, research groups across Europe are consolidating their own design practices, test protocols and environmental assumptions independently of one another. Every year without a shared basis raises the cost of establishing one later, because divergent practice becomes embedded in software, in test facilities and in the training of the engineers who will inherit the field. The window in which convergence remains inexpensive is open now, and it is closing.

The societal case is equally direct. Substantial populations remain without dependable connectivity because terrestrial infrastructure cannot be justified economically at low population density; natural disasters remove that infrastructure at precisely the moment communication matters most; and observing atmospheric processes relevant to climate requires a combination of spatial detail and revisit frequency that neither satellites nor conventional aircraft provide. Stratospheric platforms address all three, in civil applications throughout. The obstacle is not a shortage of ambition or of capable research groups. It is the absence of a common engineering foundation.

1C. State-of-the-art

The state of the art is advanced within each contributing discipline and weakly connected between them. The Action builds on the first condition and exists to correct the second.

Non-linear aeroelasticity of very flexible structures. Geometrically exact beam formulations, strain-based and intrinsic descriptions, and coupled fluid–structure approaches are all well developed and capable in principle of representing the large deflections characteristic of this vehicle class. The limitation lies not in formulation but in validation: experimental data for structures of the relevant slenderness is scarce, held in incompatible formats and obtained under conditions that differ between laboratories, so competing formulations cannot be ranked against one another. Flutter onset at large static deflection, and gust response of an already strongly deformed configuration, remain genuinely open questions — but a substantial part of the apparent disagreement in the literature originates in differing set-ups rather than in differing physics, and at present there is no way to tell the two apart.

Low-Reynolds-number aerodynamics and propulsion. Airfoil and propeller design practice rests on correlations established well above the Reynolds numbers encountered at stratospheric altitudes, and their extrapolation into this regime is neither uniform nor systematically validated. Transition prediction, which governs performance here more strongly than at conventional scales, is the principal source of uncertainty. Experimental verification is constrained by the small number of facilities able to reproduce low density and low Reynolds number together, and access to them is uneven.

Energy, thermal and materials behaviour. Photovoltaic collection, electrochemical storage and propulsive consumption are individually well characterised; what diverges between published studies is the closure of the diurnal energy balance under realistic atmospheric variability and month-scale degradation — precisely the coupled quantity that determines viability. Thermal behaviour is documented at component level, while validated system-level models remain rare. The response of thin polymer films and ultra-light composites to prolonged ultraviolet and particle exposure at low temperature is documented only in fragments, and there is no agreed accelerated-testing protocol, so results from different laboratories cannot be aggregated into design allowables — the form in which a designer actually needs them.

The stratospheric environment and its regulation. Reanalysis products, radiosonde ascents and remote sensing provide extensive observational coverage of the lower stratosphere, but no design-oriented specification has been derived from them: no agreed gust spectra, no agreed statistics of wind persistence for station-keeping, no agreed turbulence description at these altitudes. Each group constructs its own, and the divergence propagates into every dependent result. Regulatory treatment of platforms operating above conventionally controlled airspace is meanwhile uneven across Europe and developing faster than the technical evidence available to inform it; certification pathways for vehicles of this endurance and construction are not established.

Former and existing efforts. National programmes and industrial demonstrator activities have addressed subsets of this problem, and collaborative research projects at European and international level have advanced individual disciplines within it, in several cases substantially. An earlier European networking effort took up high-altitude platforms two decades ago, but concentrated on communications payloads and the services they enable rather than on the design of the vehicle carrying them; the component technologies that make sustained flight plausible have changed fundamentally since, and the structural, aerodynamic and durability questions it did not address are precisely those that now govern feasibility. Networks remain active in adjacent domains — uncrewed aviation, satellite and non-terrestrial communications, atmospheric science — and the Action will connect to them instead of duplicating their work. None, however, spans the coupled design problem for this class of vehicle, and none has produced the shared basis on which the separate advances could be compared or combined.

How the Action advances the state of the art. Not by proposing new formulations — properly the work of the research projects participants conduct under national funding — but by supplying what those projects individually lack and cannot individually create: an agreed specification of the stratospheric design environment; an open coupled benchmark and validation suite; harmonised accelerated-degradation and test practice, so durability data becomes aggregable; interface definitions permitting coupled treatment of domains presently addressed in sequence; and a consolidated evidence base for the regulatory questions.

This is an advance in the infrastructure of knowledge rather than in any single result, and it is the advance without which individual results cannot accumulate. It carries a specific scientific consequence: once set-ups are held in common, the disagreements that survive are real ones, and the field can direct effort at questions that are genuinely open instead of at artefacts of method. Establishing which stratospheric design problems remain unsolved, as distinct from merely unresolved, is itself a contribution to the state of the art.

1B. Objectives

The objectives follow directly from the diagnosis above: the field advances within domains but does not accumulate across them, because it lacks a shared basis rather than a missing result. Each objective below therefore produces something the participating groups cannot produce individually, and each is a convening or consolidation outcome, not a research finding — which is what makes it achievable within four years and appropriate to the instrument.

Research coordination objectives

RC1 — An agreed specification of the stratospheric design environment (Years 1–2). A common description of conditions between 18 and 22 km for design purposes: atmospheric state, gust and turbulence description, statistics of wind persistence relevant to station-keeping, and ultraviolet and particle exposure. Success is measured by adoption, not publication — the specification becomes the common input to all four Working Groups and is released for use beyond them.

RC2 — An open coupled benchmark and validation suite (Years 2–3). At least eight coupled reference cases spanning non-linear aeroelastic, low-Reynolds-number aerodynamic, thermal and energetic behaviour, with stated conditions, acceptance metrics and reporting format, so that independently developed methods can be compared directly for the first time. Target: results submitted by at least ten independent groups, four of them from outside the original network.

RC3 — Harmonised test and degradation practice (Years 2–4). Common protocols for accelerated ultraviolet, thermal and mechanical ageing of thin films and ultra-light composites, validated through an inter-laboratory round-robin campaign across at least five laboratories, so that durability results become aggregable into design allowables instead of isolated observations.

RC4 — Interface definitions for coupled treatment (Years 1–3). The terminology, variable sets and data-exchange conventions allowing structures, aerodynamics, propulsion, energy and atmospheric environment to be handled as a coupled system rather than in sequence, demonstrated on at least two complete benchmark cases.

RC5 — A consolidated evidence base and the Roadmap (Years 3–4). The technical material relevant to certification, airspace integration and long-duration operation, delivered as the European Stratospheric Flight Design Roadmap: a structured account of what is technically settled, what remains genuinely open, and what regulators require in order to act. Developed through four workshops with authorities and standardisation bodies, and issued for consultation before publication.

Capacity building objectives

CB1 — Distribute design capability (Years 1–4). Capability in coupled stratospheric design is concentrated in a small number of groups. Four Training Schools admitting at least thirty participants each, at least half from outside the network, together with at least forty mobility grants and openly licensed teaching material, place that capability within reach of communities where it is still emerging — so that the ability to contribute ceases to depend on location.

CB2 — Develop the next generation into scientific leaders (Years 1–4). Early-career researchers take Working Group Vice-Leader positions and coordinate Action activities, paired with experienced participants, not left nominal, with at least eight mobility grants reserved for placements hosted by industrial participants.

CB3 — Build a durable interface between academia, industry and regulation (Years 1–4). Atmospheric science, aviation regulation and telecommunications interact with stratospheric vehicle engineering only sporadically today, and industry interacts with it late. Four industrial review sessions, four regulatory workshops and a standing advisory group establish the regular working contact that RC1 and RC5 presuppose, and leave behind a community able to convene without the Action.

The objectives are ambitious in that no equivalent shared basis exists for this vehicle class anywhere, and the Action undertakes both to create one and to have it adopted beyond its own membership. They are achievable because none commissions new research: each consolidates, harmonises or transfers existing work, and each rests on activities the instrument is designed to support.

1D. Rationale for choosing networking to address the main challenge

The deficit identified above is structural rather than material. It is not that a particular calculation has not been funded, but that the results of many well-funded calculations cannot be placed alongside one another. This distinction determines the choice of instrument, because a research project and a network do not address the same kind of deficit.

Comparability cannot be produced by a single consortium. A generously funded project could produce excellent results expressed in its own conventions, against its own reference cases, using its own description of the atmosphere. It would thereby add one further incompatible body of work to a field that already has several. A shared basis is shared only if the community adopts it; a basis adopted by one consortium is not a basis at all, but a preference. The objectives of this Action are therefore achievable only through an instrument whose defining feature is breadth of participation.

The necessary capability already exists and is distributed. Non-linear aeroelasticity, low-Reynolds-number aerodynamics, energy and thermal systems, materials durability, atmospheric science and aviation regulation are held by groups that are already established, already equipped and already committed to nationally funded programmes. No project could recruit this capability; it could at best fund a fraction of it and duplicate the rest. Networking connects what exists instead of rebuilding a portion of it, which is both the cheaper and the more complete route.

The decisive physical assets cannot be centralised. Facilities able to reproduce low density at the relevant Reynolds number, thermal-vacuum chambers, test rigs for members of extreme slenderness, flight-test permissions and atmospheric observation infrastructure are geographically fixed and nationally funded; they cannot be replicated inside any project budget. What can be organised is access — coordinated campaigns, common protocols and the movement of researchers between them. Mobility instruments address exactly this; funding a single site would not.

Protocols are transferred by people, not documents. Much of what distinguishes one laboratory's measurement from another's is tacit: how a specimen is mounted, how a boundary condition is realised, what is quietly corrected. A written protocol does not convey this, which is why harmonisation based on documents alone routinely fails. Placing a researcher inside another group's facility for several weeks does convey it, and RC3 is achievable only by that route.

Adoption requires duration. Agreeing a design environment specification is not complete when a document is issued but when groups use it in preference to their own — which requires drafting, contested revision, demonstration on shared cases and repeated convening over years. Four years of sustained contact is the mechanism, and it is not something a project delivers as an output.

Openness is the source of the outputs' authority. In the absence of a formal standards mandate, a specification carries weight with regulators and technical committees according to how broadly and how openly it was arrived at. An Action whose Working Groups remain open throughout its lifetime to any researcher with a legal affiliation, and whose Management Committee gives each participating country a formal seat, produces material with standing that a closed consortium's document cannot acquire at any budget.

Some participants can be reached in no other way. Civil aviation authorities, airspace management organisations, meteorological services and standardisation committees take part in open consultative networks. They do not become subcontractors in research projects, and their contribution to RC1 and RC5 is indispensable. The network form is not merely the better instrument here; it is the only one available.

The alternative is already under way. Should nothing be done, each national effort will continue, publish and embed its own practice in software, facilities and training, exactly as described above. A research project would not slow this process; it would participate in it. The counterfactual to this Action is not stagnation but accelerating divergence, and the expense of reversing it grows every year.

The research itself will continue to be carried out by the participants under their own national funding, as it should be. What the Action supplies is the only thing that funding cannot buy severally: the shared basis that makes the resulting work cumulative.

1E. Critical mass of the network

The network assembles the disciplines the challenge requires and is deliberately structured to grow into the areas where it is at present thinner.

Expertise assembled. The Action brings together established capability in the non-linear aeroelasticity and structural dynamics of highly flexible members; in ultra-light and composite structures, including their manufacture and experimental characterisation; in structural metrology; in model-based design of solar-powered uncrewed platforms; in aerodynamics and propulsion at low Reynolds number; in systems-level design and mission analysis of stratospheric platforms; and in aviation operations and regulation. This capability is distributed rather than concentrated, and several participants operate the experimental facilities on which the harmonisation objectives depend. Industrial participants in composite production and aerospace systems ensure that outputs are assessed for manufacturability as they are produced rather than afterwards. Every objective has identified capability behind it at the outset.

Where the network is thinner, and how it will grow. Three areas require deliberate strengthening: atmospheric science, on which the environment specification depends; telecommunications and non-terrestrial network engineering, which sets the service requirements driving design cases; and specialist aviation law with airspace integration, which the Roadmap requires. The plan for each is concrete, and rests on the openness of Working Group membership described above. Capability in each area is identified during the capability mapping task and invited directly, with the Stakeholder Advisory Group providing the route into regulatory and standardisation communities. Training Schools and mobility function as a second channel, since researchers who attend frequently remain. The benchmark suite is itself the most effective recruitment instrument available: groups working on these problems have a direct interest in having their methods represented in the comparison, and participation is the only way to achieve that.

Ensuring engagement is meaningful. Participation is defined by task, not by membership. Every participant is attached to a task with a named deliverable and a date; the Custodian records contributions to shared artefacts under version control; Working Group Leaders report participation to the Core Group at each plenary; and the Management Committee reviews annually whether each strand has the capability it requires. A participant who is present but not contributing is visible within one reporting cycle, not at the end of the Action.

2. IMPACT

2A. Impact related to objectives

The Action's principal impact is structural: it converts largely disconnected efforts across Europe into a coherent capability for the design of stratospheric vehicles. Every impact described below rests on aligning work that is already funded and under way, which is what makes them realistic rather than aspirational.

Impact on scientific knowledge (short to medium term). Within its first two years the Action will deliver a commonly agreed description of the stratospheric design environment, together with an openly documented suite of validation cases covering the coupled aeroelastic, aerodynamic, thermal and energetic behaviour that governs vehicles at these altitudes. Research on High-Altitude Pseudo-Satellites (HAPS) is at present produced against locally chosen assumptions; this is the first mechanism by which that ceases to be so. The impact is immediate and measurable: results become comparable between groups, duplicated validation effort falls, and the field acquires a common yardstick against which new methods can be judged.

The same mechanism serves a second scientific purpose. Stratospheric vehicle design is governed by couplings presently treated in sequence: structural flexibility alters aerodynamic loading, loading alters propulsive requirement, propulsion alters the energy balance, and the energy balance alters mass and therefore flexibility again, while the atmosphere acts on all of them at once. Each domain is well developed in isolation and carries its own vocabulary and validation traditions, which is precisely why the couplings remain poorly served. The shared terminology, interface definitions and data-exchange conventions the Action establishes allow them to be treated together — an impact reaching beyond stratospheric flight, since the same coupling arises across other classes of ultra-light, solar-powered and long-endurance vehicles.

Impact on technology and industry (medium term). The Action's technical outputs — design guidelines, the benchmark suite, and consolidated practice for qualifying ultra-light structures under prolonged exposure — will be openly available. This lowers the entry barrier for small and medium-sized enterprises and for emerging aerospace research communities, which at present must rediscover much of the design space independently and at disproportionate cost. Participants from industry keep outputs implementable, not purely academic, making transfer continuous instead of a final dissemination step.

Impact on policy and regulation (medium to long term). Stratospheric platforms occupy a regulatory gap: they operate above conventionally controlled airspace yet must transit it, they are neither aircraft in the established sense nor satellites, and the frameworks governing their certification, airspace integration and long-duration operation remain incomplete and unevenly developed across Europe. The gap cannot be closed without a consolidated technical evidence base, and none exists. The Action will produce one, consolidated by a dedicated Working Group into a European Stratospheric Flight Design Roadmap setting out available technical solutions, operational considerations and the regulatory questions that remain open. This gives civil aviation authorities, airspace management bodies and standardisation organisations material they can act upon, and positions the European community to contribute to international standardisation discussions rather than merely respond to them.

Impact on society (long term). The applications enabled are civil throughout: low-latency connectivity for remote regions where terrestrial infrastructure is uneconomic, rapid restoration of communications where disaster has destroyed it, and continuous observation of the atmosphere and surface at a combination of resolution and revisit rate satellites cannot achieve. By strengthening the design basis for such platforms the Action contributes to services addressing connectivity inequality, disaster resilience and environmental monitoring. The Action addresses exclusively peaceful purposes.

Impact on research coordination. The Action replaces parallel, weakly connected activity with a shared agenda, in three ways. It maintains a mapped picture of where capability and gaps across Europe actually lie, so effort is not spent on questions already answered elsewhere. It establishes agreed methodologies and shared validation data, so separately funded national projects produce results that accumulate rather than merely coexist. And it creates a standing forum where none currently exists — one intended to outlast the Action, since within four years the community will be structured well enough to prepare joint follow-up proposals for collaborative research funding, for which a COST Action is an established entry point.

Impact on capacity building. Advanced simulation and design capability for coupled stratospheric problems is concentrated today in a small number of research-intensive groups. Through Training Schools, Short-Term Scientific Missions, virtual mobility and open teaching material, the Action distributes it far more widely, so that the ability to contribute is no longer determined by where a researcher is based. Leadership roles are extended to the next generation at a career stage when such opportunities are rare, and the sustained presence of industrial alongside academic participants builds a bridge neither side maintains reliably alone.

Why these impacts are realistic. Each is tied to a specific deliverable at a defined point in the work plan. The short-term impacts depend only on convening the network; the medium-term impacts on aligning what participants are doing anyway; the long-term impacts on the evidence base assembled, pursued through channels engaged from the first year, not approached at the end. The Action does not claim to build a stratospheric vehicle. It claims to give Europe the common design basis without which building one remains a series of isolated attempts.

2B. Involvement of stakeholders

The outputs of the Action matter only if they reach the people who design stratospheric vehicles, the authorities who will permit them to fly, and the operators who will use them. Engagement is therefore built into the structure, not appended to it: one Working Group exists specifically to convert technical findings into material non-academic actors can act upon, and each Working Group engages the categories closest to its own work. COST Working Group membership is open throughout an Action's lifetime to anyone with a legal affiliation, so stakeholders can participate fully without having been part of the original network — an openness the Action uses deliberately and continuously.

Industry and small and medium-sized enterprises. Manufacturers of ultra-light structures, composite components, propulsion and energy systems are engaged from the first year as Working Group members, hosts for Short-Term Scientific Missions and trainers in Training Schools. Their role is to test every guideline and benchmark case against what can actually be manufactured, qualified and maintained, and to identify where academic assumptions break down in production — preventing the Action from producing an internally consistent body of work that no one can build. The challenge is not underestimated: smaller companies cannot release engineering staff for open-ended commitments. Engagement is therefore built from short, defined contributions — one review round on a draft guideline, one hosted mobility visit, one training contribution — and around outputs the companies can use in their own work, so that participation returns value rather than only consuming it.

Civil aviation authorities and national regulators. Regulators are engaged as consultative participants through dedicated workshops and structured review of successive Roadmap drafts. Their role is to indicate what evidence they would need before stratospheric operation could be regulated with confidence, so that technical effort is directed at the questions that actually block progress instead of those the research community finds most interesting; an evidence base assembled without knowing the regulator's questions is unlikely to answer them. The challenge is one of standing: authorities cannot endorse, co-author or pre-commit to positions developed in a research network. Engagement is consequently framed as consultation rather than co-production, all outputs remain the responsibility of the Action, and no participating authority is presented as endorsing them.

Airspace management organisations and the unmanned traffic management community are engaged through the same workshops, to work through concrete integration scenarios — ascent and descent through controlled airspace, contingency handling, long-duration station-keeping. Their added value is operational realism that cannot be reconstructed from published material; the challenge is that they work to timescales driven by live service obligations, so their involvement is concentrated in scheduled sessions rather than continuous.

Standardisation bodies and technical committees. These are targeted as recipients of structured technical input: consolidated terminology, agreed environmental definitions, and test and qualification practice. Their added value is durability, since material absorbed into standardisation work outlives any network. The challenge is timescale, and the Action is explicit about it: standardisation cycles run longer than four years, so the objective is well-formed input to committee work in progress, not a claim that a standard will be adopted within the Action's lifetime.

Telecommunications operators and service providers. They define, at the level of service requirements, what a stratospheric platform must deliver in endurance, payload capacity, availability and coverage — the parameters that set the design cases used across the technical Working Groups, anchoring the design envelope in demand rather than assumption. The challenge is commercial confidentiality, addressed by working at the level of generic service requirements, not any company's roadmap.

Meteorological services and atmospheric research infrastructures. They provide, review and validate the description of the stratospheric environment that underpins the whole technical programme, and advise on the atmospheric interaction questions raised by sustained operation. Their added value is authoritative data in place of locally chosen assumptions. The challenge is that data access is governed by licensing arrangements varying between providers; the Action will work with openly licensed products wherever possible and document provenance in all cases.

The wider research community. Training Schools, mobility grants and Working Group membership are open beyond the participating institutions and advertised openly, in order to broaden the base of expertise and draw in adjacent disciplines that no single consortium assembles completely at the outset. The challenge is visibility, addressed through open advertisement of every activity and active outreach to communities where stratospheric research capability is still emerging. Policy makers are addressed separately and later, principally through the Roadmap and targeted briefings in the final year; because policy attention is episodic, the Roadmap is written as a usable reference document, not an advocacy paper.

The Stakeholder Advisory Group described under the Action structure is the mechanism by which this engagement is reviewed and adjusted each year.

2C. Communication, dissemination and valorisation

The Action distinguishes three activities that are often conflated. Communication makes the existence and purpose of the work known; dissemination places specific results in the hands of those able to use them; valorisation turns those results into continuing use beyond the Action. Each is directed at a defined audience through a channel appropriate to it, and each is the responsibility of a named role — the Science Communication Coordinator for communication, the Working Group Leaders for dissemination within their domains, and the Core Group for valorisation.

Communication. A public website, established in the first six months, presents the challenge and the Action's activities in language accessible to non-specialists and announces every Training School, workshop and mobility call. Short explanatory material — brief articles and visual explainers — describes what stratospheric platforms are for in civil terms: monitoring the climate, restoring communications after disasters, connecting regions terrestrial networks do not reach. This is aimed at the general public, at students considering the field, and at the communication offices of participating institutions, which are supplied with ready-to-use content so that reach multiplies without additional effort.

Dissemination. The research community is addressed through open-access publications, joint position papers written across Working Groups rather than within them, and open workshops co-located with established international conferences, which reach an audience far larger than the network at modest cost. The technical products — the environment specification, the benchmark suite, the design guidelines and the consolidated test practice — are deposited in a recognised open repository under open licences, following FAIR principles, with versioning and citable identifiers. Industry and regulators are addressed through targeted formats, not journal articles: concise guideline documents, workshop briefings and successive consultation drafts of the Roadmap. Training Schools and open teaching material carry results to the next generation and are available for reuse in university teaching. COST conference grants are used systematically to enable participants — in particular early-career participants and those from countries where such travel is otherwise difficult to fund — to present Action results externally.

Valorisation and exploitation. Three routes are pursued deliberately. The technical outputs are structured from the outset as input to standardisation work in progress, so that they are formatted and evidenced as technical committees require and need no later translation. The design guidelines and benchmark suite are released in a form directly usable by small and medium-sized enterprises and by research groups entering the field, which is how the Action lowers the barrier to entry instead of merely describing it. And the Roadmap identifies the questions still open at the end of the four years, giving the community the basis on which to assemble the follow-up research described under Impact.

Intellectual property. COST funds networking rather than research, and the results the Action generates are pre-competitive by nature: terminology, shared environmental definitions, benchmark cases, guidelines and review material. These are released openly. Background knowledge brought by participants, and in particular the proprietary know-how of industrial participants, remains entirely with its owners; results are described at a level of abstraction that does not compromise it. The Management Committee will adopt a short written understanding on intellectual property and on the handling of shared data at its first meeting, so that the terms are settled before rather than after material begins to circulate.

3. IMPLEMENTATION

3A. Action Structure

The Action is organised so that no Working Group can complete its own work without consuming the output of another, and so that shared artefacts have named owners, not collective ones.

WG1 — Structures, aeroelasticity and materials. The behaviour of very slender, highly flexible structures under large deflection, and the durability of thin films and ultra-light composites under prolonged exposure. WG1 owns the structural portion of the benchmark suite (RC2) and the ageing protocol (RC3).

WG2 — Propulsion, energy and thermal management. Aerodynamic and propulsive performance at Reynolds numbers of order 100 000, and closure of the diurnal energy balance including thermal behaviour. WG2 owns the aerodynamic, propulsive and energetic portion of the benchmark suite (RC2) and leads the demonstration of coupled treatment (RC4).

WG3 — Atmospheric environment, payloads and services. The description of the operating environment and the service requirements that set design cases. WG3 owns the environment specification (RC1) — the single input consumed by every other Working Group — and translates payload and service demands into the performance envelopes against which designs are assessed.

WG4 — Regulation, airspace integration and Roadmap. Certification pathways, airspace integration and operational frameworks, assembled into the European Stratospheric Flight Design Roadmap (RC5). WG4 is a consumer of the technical Working Groups by design, and returns to them the questions regulators need answered, which is how the Action keeps its technical work pointed at what blocks progress.

Interrelation. The dependencies are explicit and directional. WG3 supplies the environment specification WG1 and WG2 require before their benchmark cases can be defined; WG1 and WG2 jointly own the benchmark suite and cannot complete it separately, since the cases are coupled by construction; WG4 cannot assemble the Roadmap without all three, and in turn shapes their later work. A structure in which the Working Groups could succeed independently would reproduce the fragmentation the Action exists to correct.

Leadership and additional roles. The Management Committee governs, supported by a Core Group of the Action Chair, Vice-Chair, four Working Group Leaders, Science Communication Coordinator and Grant Awarding Coordinator. Each Working Group has a Leader and a Vice-Leader, the latter filled by early-career researchers working alongside experienced Leaders — delivering CB2 through the management structure itself, not as a separate activity. Three roles beyond the mandatory ones address specific failure modes. A **Benchmark and Data Custodian** holds responsibility for the integrity, versioning and release of the benchmark suite and environment specification: shared artefacts owned by everyone are maintained by no one, and assigning custody is what allows RC1 and RC2 to remain usable after the Action ends. An **Integration Task Force**, one member per Working Group meeting quarterly, owns the interface definitions (RC4) and is the structural answer to the sequential treatment of coupled domains. A **Stakeholder Advisory Group** from industry, regulatory authorities and standardisation bodies meets annually with the Core Group to assess whether outputs remain usable by those expected to apply them.

Internal communication. Working Groups meet twice yearly, once alongside a plenary Management Committee meeting and once independently, with virtual meetings between. A shared repository holds all working material under version control from the first month, and the Custodian issues a documented release of each shared artefact at defined points, so participants always know which version is current.

3B. Work plan (tasks, activities and timeframe)

The work plan follows a four-year cycle of specify, populate, compare and consolidate. Each year closes on a milestone that the following year depends upon, so that slippage becomes visible immediately, not only at the end.

Year 1 — Specify. *T1.1* Each Working Group maps capability and gaps in its domain, consolidated into a single account of where European capability actually lies. *T1.2* The Integration Task Force agrees common terminology and a first definition of the interfaces between domains. *T1.3* WG3 drafts the environment specification from observational and reanalysis sources. *T1.4* WG1 and WG2 jointly define the benchmark case set, run conditions and reporting format. *T1.5* WG4 surveys the regulatory landscape and convenes the first workshop with authorities. **M1 (month 12): terminology, interface definitions v1 and the capability and gap map published.**

Year 2 — Populate. *T2.1* The environment specification is revised against Working Group use and released as v1.0. *T2.2* Independent groups run the benchmark cases and submit results in the agreed format; the Custodian assembles the first cross-comparison. *T2.3* WG1 drafts the accelerated ageing protocol and designs the round-robin campaign. *T2.4* The Integration Task Force demonstrates coupled treatment on a complete benchmark case. *T2.5* WG4 produces the Roadmap outline. **M2 (month 20): environment specification v1.0 released and adopted as common input.**

Year 3 — Compare. *T3.1* The cross-comparison is analysed to separate genuine methodological disagreement from artefacts of differing set-up, and the surviving open questions documented. *T3.2* The round-robin ageing campaign is executed. *T3.3* Design guidelines are drafted from the comparison outcomes and industrial review. *T3.4* WG4 circulates a full Roadmap draft for consultation. **M3 (month 32): first complete cross-group benchmark comparison, with open questions identified.**

Year 4 — Consolidate and transfer. *T4.1* Design guidelines are finalised, industrially reviewed and released. *T4.2* Round-robin results are consolidated into durability data usable as design allowables. *T4.3* The benchmark suite is released in documented form with long-term custody arranged beyond the Action. *T4.4* The Roadmap is finalised and delivered. *T4.5* The community agrees a continuation agenda and the basis for follow-up proposals. **M4 (month 46): European Stratospheric Flight Design Roadmap delivered.**

Activity plan. The Gantt chart sets out the full schedule. Its pattern is fixed and repeating, so that participants can plan against it from the first year: eight plenary events, each combining a Management Committee meeting with meetings of all four Working Groups; four thematic Working Group workshops; four Training Schools; at least forty mobility grants across four calls; four industrial review sessions; four regulatory workshops; two open workshops and a final conference.

Two elements deserve comment because they carry the harmonisation objectives. **Four coordinated facility campaigns** replace the scattered individual visits that characterise this field today: the aerodynamic and propulsive benchmark cases; characterisation of highly flexible structural specimens;

the inter-laboratory round-robin ageing campaign across at least five laboratories; and verification of the coupled cases. Each is preceded by a protocol agreement session and followed by joint reporting. **Mobility is awarded in three categories** — protocol transfer visits, benchmark execution visits, and industrial placements, of which at least eight are reserved for early-career researchers. The industrial review sessions are held at participants' own premises and on the manufacturing floor, beginning with a briefing in which industry states what actually constrains it.

Risk is managed by sequencing rather than by contingency. The environment specification precedes the benchmark cases, and the benchmark cases precede the guidelines, so that a delay is contained within one strand instead of propagating. Where a Working Group depends on an input that is late, the Integration Task Force is empowered to release a provisional version under explicit assumptions, which are recorded and revised when the definitive version arrives. Facility campaigns carry the highest schedule risk because they depend on host availability; each is therefore scheduled with a spare window in the following quarter, and the protocol agreement session is held early enough that a campaign can be relocated to an alternative host without renegotiating its content.

3C. Deliverables

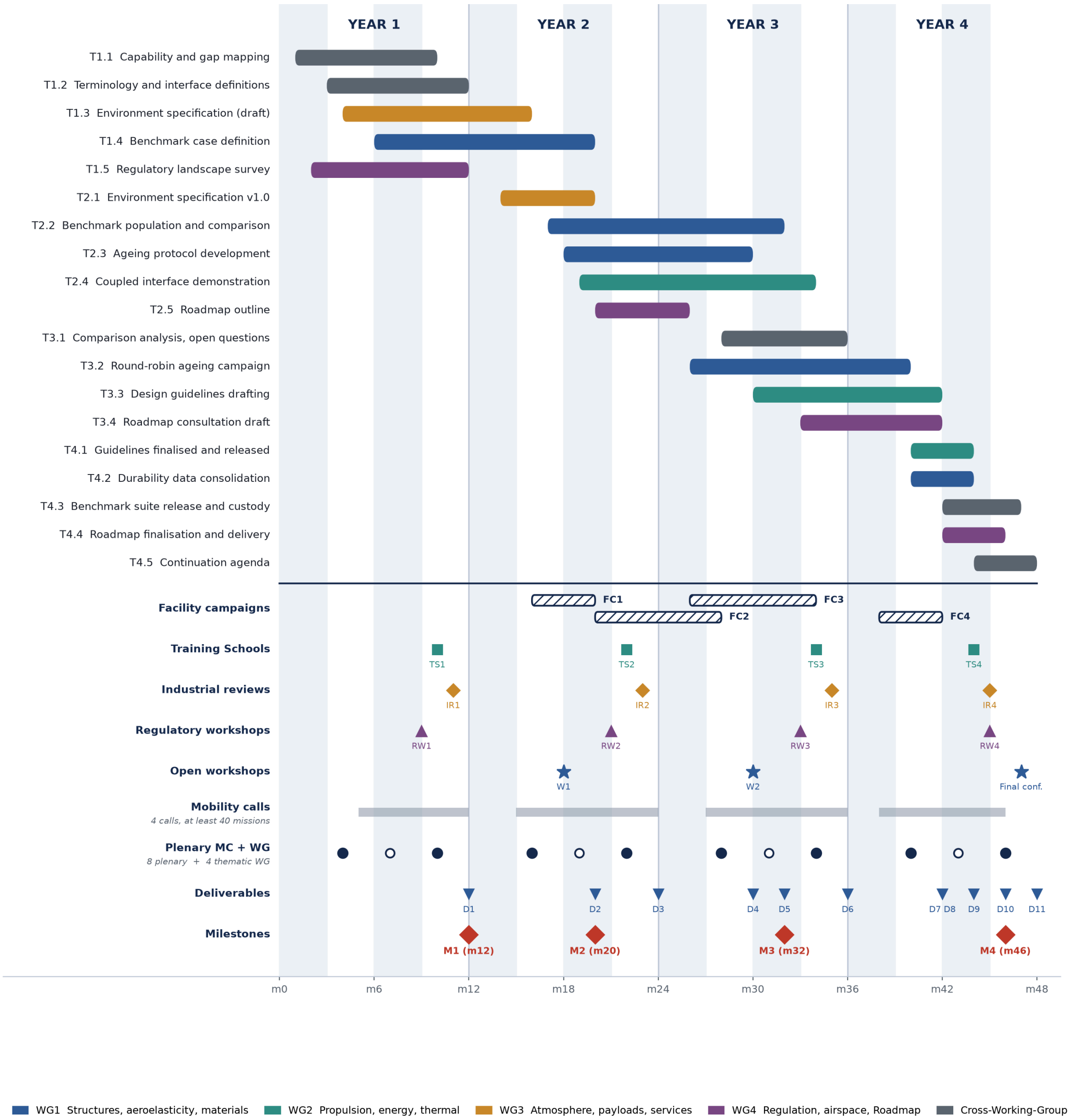
Each deliverable below is a tangible artefact. The objectives it serves are given in brackets; the substance of each is described under those objectives and is not repeated here.

	Deliverable	Month	Form
D1	Capability and gap map, with agreed terminology *(RC4)*	12	Report
D2	Stratospheric Design Environment Specification v1.0 *(RC1)*	20	Specification document
D3	Benchmark and validation case set *(RC2)*	24	Open repository, versioned, citable
D4	Harmonised accelerated ageing and test protocol *(RC3)*	30	Protocol document
D5	Cross-group benchmark comparison report *(RC2)*	32	Report
D6	Interface definitions and data-exchange conventions v1.0 *(RC4)*	36	Technical specification
D7	Design guidelines for stratospheric vehicle configurations *(RC2, RC3)*	42	Guideline document, industrially reviewed
D8	Consolidated durability dataset and design allowables *(RC3)*	42	Dataset
D9	Open teaching material set *(CB1)*	44	Curriculum, lectures, exercises, open licence
D10	**European Stratospheric Flight Design Roadmap** *(RC5)*	46	Roadmap — the flagship deliverable
D11	Structured input to standardisation committees *(RC5)*	48	Committee submission

Two points on form. D3 and D8 are released in an open repository under open licences with citable identifiers, so that they can be referenced and extended after the Action ends; D11 is not new content but D2, D4 and D6 reformatted to the evidentiary conventions technical committees require. Open-access publications and joint cross-Working-Group position papers are produced throughout and not listed separately, being continuous outputs, not dated artefacts.

3D. Gantt chart

Work plan and activity schedule



Activity summary

Activity	Number	Timing
General assembly (MC and all four Working Groups together)	**8**	twice a year — months 4, 10, 16, 22, 28, 34, 40, 46
Thematic Working Group workshop	**4**	once a year — months 7, 19, 31, 43
Core Group	16	four a year (two in person, two online)
Integration Task Force	16	quarterly, online
Training School	**4**	months 10, 22, 34, 44 — each with at least 30 participants, at least half from outside the network

Activity	Number	Timing
Facility campaign (laboratory)	**4**	FC1 months 16–20 · FC2 20–28 · FC3 26–34 (at least five laboratories) · FC4 38–42
Industrial review session (company visit)	**4**	months 11, 23, 35, 45 — at the industrial partner's own premises
Regulatory workshop	**4**	months 9, 21, 33, 45
Stakeholder Advisory Group	4	annually, alongside the autumn general assembly
Open workshop and final conference	**3**	months 18, 30, 47
STSM / mobility grants	**≥40**	four calls — protocol transfer, benchmark runs, industrial placements (at least 8)
Conference grants (ITC, young researchers, dissemination)	~30	ongoing