

Technology acceleration process for the THEMIS low cost and reusable prototype

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Abstract

While Ariane 6 and Vega-C are about to be fielded and entering operations, CNES and ArianeGroup are already actively preparing next generation of European launchers. With the PROMETHEUS oxygen/methan engine starting subsystems testing in 2018, and the CALLISTO experimental reusable vehicle about to complete Preliminary Design, engineering work has been initiated for next step on the European roadmap: THEMIS. THEMIS is both a demonstrator and a prototype of a low cost and reusable first stage, meant as the centrepiece of future Ariane architectures. It is intended to feature PROMETHEUS and will build upon technologies and lessons learned from the CALLISTO programme. Several challenges lie ahead for THEMIS, with two highlights: meeting an aggressive cost targets consistent with the 50% launch cost cut sought beyond Ariane 6, and keeping a swift tempo for getting THEMIS ready well before 2025. To address those challenges, a specific initiative was undertaken by CNES and ArianeGroup, under codename ArianeWorks: combining both a “Skunkworks like” approach and an open-innovation platform, ArianeWorks is tasked with getting the project done quicker and bolder than through a conventional organization. The paper will discuss the system engineering approach adopted for THEMIS design, by identifying and then allocating technical objectives related to Ariane 6 evolution/Ariane NEXT between CALLISTO and different sized THEMIS options. Then, the early hardware/testing “agile” development process will be detailed, with an aim at speeding up design iterations and technology maturations. Subsequently, the paper will introduce the initial architecture choices and technological ambitions attached to THEMIS, together with the trade-off to be performed during the first 6 months of the project.

1. THEMIS, stepping stone for future European rockets

1.1 Exciting challenges ahead

Ariane is about to turn 40 by year's end while Space Activities are at an exciting turning point: i) space apps are expanding beyond historical mission profiles, involving growing number of small spacecrafts, multipurpose constellations or lunar delivery transport, and ii) Launch landscape is being reshuffled with new rockets being fielded all around the world in just a few years' timeframe.

- i) Can be illustrated by the launch in 2019 of the first swarms of two telecommunication megaconstellations (namely OneWeb and Starlink), while projects like Amazon Kuiper or Telesat are progressing. Meanwhile, the historical geostationary missions that supported for decades the "commercial launch" economical model with 20-25 spacecrafts/year are shrinking, with just a few orders in 2018.

Additionally, small satellites (< 500 kg) are gaining momentum - not only in relation with telecom megaconstellations -, showing an exponential growth that we predict shall however flatten by 2025. Since the mid 2010ies, these formats are not anymore the exclusive realm of universities, more than half of those small birds being fielded by commercial companies, most of them new ventures, and focused on earth observation derived applications or IoT.

- ii) In a single decade, 2015-2025, new rocket types- and new actors - are going to enter operation all over the world: SpaceX Falcon Heavy/Starship, ULA Vulcan, Blue Origin New Glenn, China new modular Long March fleet (LM 6/7/5/11/9), Indian GSLV MkIII, Japan H3 or Russia Angara and Soyuz 5.

On top of this unprecedented global renewal move, more than 100 private microlaunch projects are underway, trying to surf the wave of the small satellites trend. RocketLab Electron, Virgin Orbit LauncherOne or OneSpace are among those pretenders. Despite the blooming of such projects, our analysis suggests there is eventually only room for a handful of microrockets by mid of next decade. Anyhow, this is certainly stimulating innovation, and especially cost innovation, as the most pressing challenge of microlaunch lies on design to cost (hence European Commission H2020 low cost Prize Challenge).

1.2 Introducing THEMIS in European Space Access Strategy

Previous chapter drew the background picture for European Space access strategy.

First and necessary move is the improvement brought by Ariane 6 and Vega-C as soon as next year: quick and smart redesign that brings for Ariane segment more than 40% cost cut. Not many industrial sector can claim such a step in a few years' timeframe.

Beyond that, European strategy is taking shape under codename "**Ariane NEXT**" (see ambitions set in [1] and earlier in [2]): objective here is to enable another factor 2 on access to space costs over a decade, for any useful format (i.e. microsatellite to Ariane classical "big birds"), so as to get prepared to serve opportunities highlighted above, and being tuned to future worldwide competition. CNES and ArianeGroup stand at the forefront of this strategy in Europe, opening meaningful paths that others are joining.

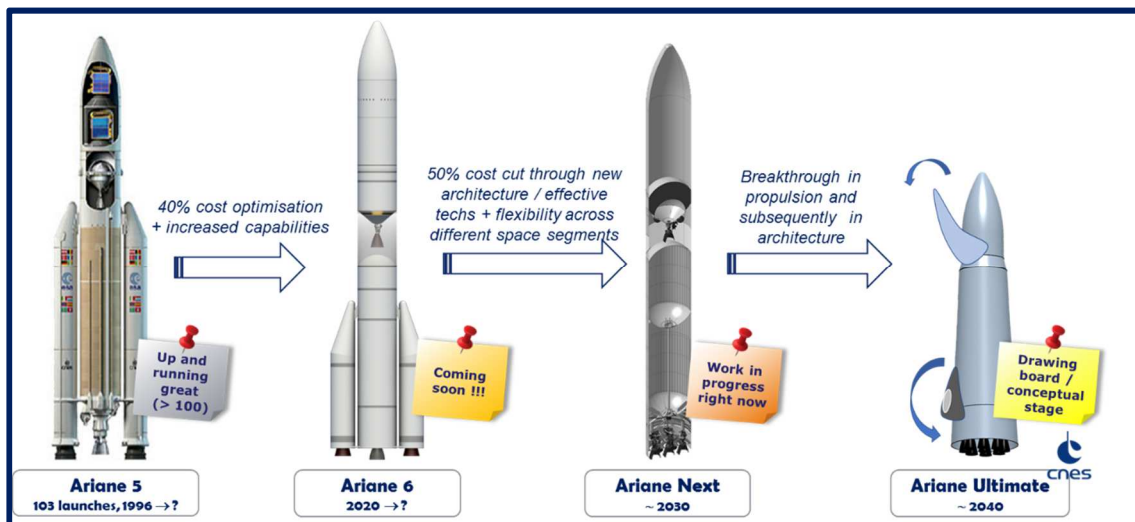


Figure 1 - Ariane notional strategy over 4 generations

As one can understand from the unstable situation depicted above, there is nothing but certain in Ariane NEXT, be it on time-line or on architecture: design options will be frozen later on the road as new space applications and smart strategies will unfold. Actually, even the format/performance class of the Ariane NEXT family is a moving target. In such a situation, smartly moving forward is about investing in "multipurpose key capabilities" that will eventually be combined in European future rockets, despite not knowing exactly how. And this is exactly what was initiated in 2014-2016 with first PROMETHEUS low cost / reusable rocket engine (10 times cheaper than Vulcain for about the same thrust, see [2]) –, and that is now being pursued with THEMIS, low cost / reusable rocket 1st stage (also significantly cheaper than comparable lower composite).

This move for THEMIS follows general trade off performed for the last 4 years (illustrated in [3]), that allowed to narrow needs and objectives. At least precisely enough to outline the relevance for a demonstrator as a "multipurpose

key capability”. Also, beyond pure technical capabilities, a set of core values were listed (see hereunder) that drives the project as much as hard requirements coming from Ariane NEXT.

It is imperative to understand that these “soft values” are at the heart of the project: speed and innovation are almost as important as performance in front of upcoming challenges, and this is why THEMIS has been undertaken through a specific management framework, ArianeWorks that shall allow to iterate and develop the project in a different way than classical Ariane organizations.

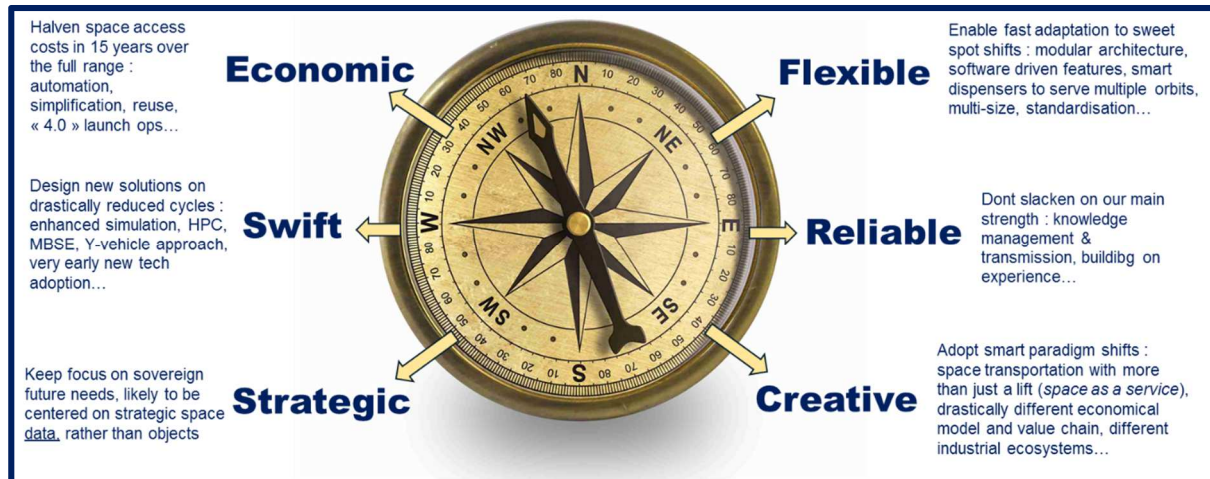


Figure 2 – Core values compass for THEMIS

2. Objectives, current status and definition

2.1 High level objectives and design heritage

THEMIS is obviously closely tied to Ariane NEXT architecture options, and the project was sparked as those options were being outlined out of both CNES national program and ESA FLPP System Studies ([1]). Not of them are shown herebelow, as some of the features are reserved, but the following list should provide a good overview on what the demonstrator shall perform:

- **Flight domain:** Mach 6-8 at 60-70 km high injection point with recovery in French Guyana, exploring very close conditions to actual Ariane NEXT toss-back first stage trajectories;
- **Propulsion:** LOX/Methane rocket stage featuring PROMETHEUS as main propulsion, helium free operations...etc.;
- **Architecture:** structural index better than 7%, common bulkhead featuring pass-through feed line, compact multiengine bay...etc.;
- **Avionics:** wireless ground/launcher communications and avionics, hybrid inertial/GNSS navigation, autonomous safety kit (based on KASSAV CNES project) ...etc.;
- **Reusability features and conops:** >5 times reusable, health monitoring strategy & system allowing contained operational costs, distant/automated operation for recovery procedures...etc.;
- **Economic:** secret, but one can imagine that there is a very strong objective in that area (as was the case for PROMETHEUS), which in turns drives manufacturing concepts and some of the architecture options. In other word, THEMIS is a low cost and reusable stage, in this priority order. Meeting manufacturing/operations costs targeted is on the key expectations for this project, beyond reusability demonstration.

Design heritage is also worth mentioning here, as THEMIS is building upon smaller scale vehicle experiments that shall improve European knowledge and unrisk technologies maturation beforehand. They include notably:

- FROG (introduced at this EUCASS session, [5]), which is a 1/10th scaled “sandbox” vehicle that will serve to test some of the early stage ideas in connexion with THEMIS. Wireless avionics or alternative stage recovery options are examples of topics where
- CALLISTO, which is a much more significant effort undertaken by CNES, DLR and a 3rd international partner. Objective here is to test the full toss-back manoeuvre at the Guyana European Spaceport on a vehicle that is about half the size of THEMIS. Tricky trajectory, safety management, operational concepts or flight algorithms are among the numerous areas where CALLISTO should feed THEMIS.

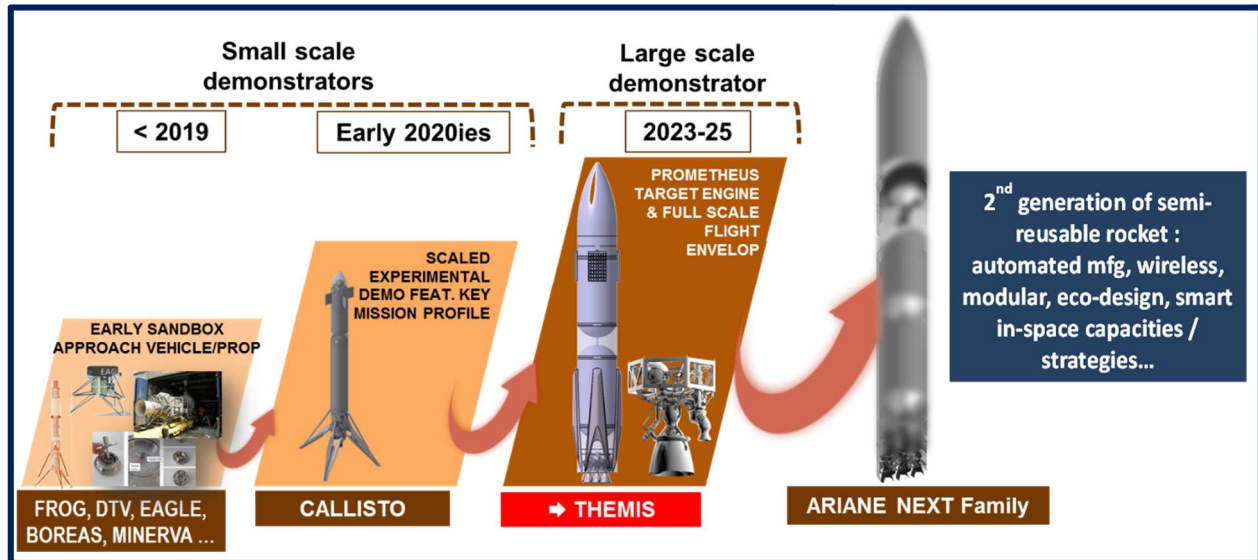


Figure 3 - THEMIS position in Ariane notional roadmap

2.2 Current status and definition

THEMIS engineering got a boost from February 2019 onwards. The project can be described as in being in a middle of phase A by space engineering standard: system engineering has gone through several iterations to refine trajectories, sizing and loading. This system-level outcome was cross-checked both by CNES and ArianeGroup, hence providing a very solid foundation for further work. Meanwhile, development logic has been drafted and some level 1 subsystem definition is underway, already involving partner's associated to ArianeWorks. Related documentation will be released ahead of ESA Ministerial Council SP19+, where the project will be proposed for a first test sequence.

As an output of this engineering sequence, Themis is defined for its main characteristics as a 30 m tall single stage vehicle, 3.5 m wide, propelled by 3 aligned 1000 kN Prometheus, and loaded with 130 T of Lox/CH₄ propellant. It shall eventually launch and land in French Guyana, with two sites being considered: Diamant zone, which is to be revived as an "experimental area" in the coming years (Callisto, private microlaunchers...), or alternatively Ariane 5 ELA3, which will be available after Ariane 5 phase out, with quite a number of associated toolings/facilities.

Thanks to this 3 engines configuration, launch / return trajectories have been carefully tuned to both fulfil representativity expected with regard to Ariane NEXT (see chapter 2.1), and at the same time cope with safety rules/corridor around the European Spaceport. Vertical landing is foreseen on a single Prometheus engine, using the throttling capability specifically developed for this engine. Noteworthy, fulfilling those trajectories characteristics does not require a very demanding mass optimization (at least when compared to rocket-science habits), which leaves a degree of freedom in project management for considering quick-and-cheap solutions whenever relevant. These system co-engineering loops heavily relied on lessons learned and simulations capabilities developed for CALLISTO in the past years, which stand another illustration on how the overall European logic is unfolding.

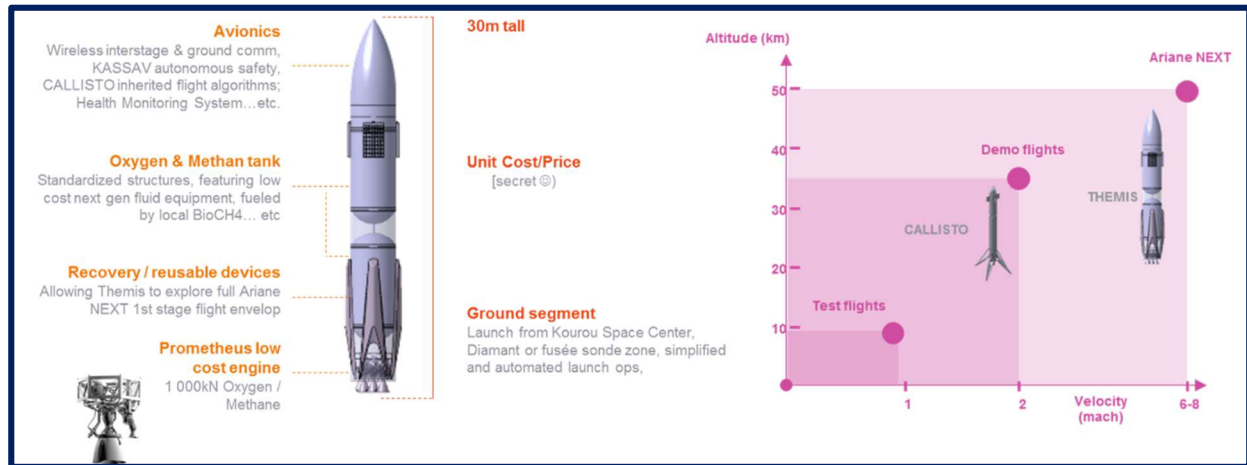


Figure 4 - THEMIS overview (note : CAD for illustration purpose, not an engineering drawing)

Full domain flight tests are targeted for 2023, while earlier hardware test are foreseen between 2020 and 2022, progressively exploring engineering areas, and stepwise gaining in complexity towards more and more demanding objectives (see chapter 3.2 below): CH₄ functional equipments/thermal management, single engine command and control, final landing sequence validation, full-representative tank geometry...etc. These earlier test occurring before 2023 are considered either in France and/or at SSC facility in Kiruna for which a feasibility study is underway.

At subsystem level, "work on progress" describes well current status, as some of the key options are under trade off right now: tank manufacturing configurations, thermal design and operational concept avoiding the need for any thermal protection, modular avionics architecture or hot gas reaction control system for flip maneuvers at stage cut off, compact multi engine aft bay...Not much detail can be shared at this stage, except the general fact that synergies are sought with existing technologies development in Europe in most cases (e.g ultra low cost thrust vectoring actuator, KASSAV autonomous safety and flight termination equipment), although in other areas more original/out of the box actions are being initiated, whenever there is a high value potential in speed/cost to the project (e.g. low cost aluminium sandwich/aluminium skin process, local bioCH₄ propellant filiere).

3. Accelerating THEMIS through ArianeWorks

The need for speed has been highlighted as a specific expectation for THEMIS project. This need is being addressed so far through 3 levers for an "experimental period" that will last until spring 2020. At this point in time, efficiency will be reviewed, tuning might occur here and there to drive the project at the best possible pace for the next 3 years under ESA framework.

The 3 levers deployed today for this purpose can be described as follows:

- **Empowered management:** a dedicated team has been assigned to THEMIS 9 month before the Ministerial Council. This team - namely ArianeWorks - involves straight forward decision making, autonomy and a dynamic mindset that shall hopefully drive the project fast forward. This is discussed just below.
- **Agile development logic:** unlike earlier attempts to elaborate THEMIS development logic, proposed way forward is not built around a phase A/B/C/D sequencing (=make it perfect right from the first time). Instead, the pace of the project is made by yearly hardware testing milestones, allowing to enter a virtuous test / redesign spiral loop as soon as we can (= build and learn as you walk).
- **Proof of Concept catalysts approach:** there are a number of areas where high risk/high gain smart ideas have been worked recently in engineering design offices (be it CNES or throughout Ariane industrial base) but would not reach sufficient TRL mark for embarking in a standard space project baseline. In those situations, attempts are made to "leapfrog" the technology maturation process by undertaking proof of concept actions, possibly allowing to shorten innovation cycles.

3.1 Empowered management: the ArianeWorks initiative

ArianeWorks is an innovation platform sparked by CNES et ArianeGroup, and aimed at accelerating the preparation of future generations of European rockets. It consists in a fully integrated project team with an unprecedented level of freedom and flexibility, combined together with the support of the experienced Ariane design offices (e.g. engineering models, test and manufacturing facilities, hardware items, patents). The team competences embrace the full scope of rocket engineering, from launch pad to propulsion or avionics, and beyond core engineering, cost modelling, business development or innovation.

This setup, qualified as an “autonomous innovation team” in innovation management literature ([2]) is mandated to steer design choices and scout original technology paths for THEMIS. Initially launched by CNES and ArianeGroup, because the two entities shared the same vision for THEMIS needs, and its position in the European roadmap, the platform is about to be enlarged to 5 international industrial/research partners, sharing the vision, bringing manpower, back office support and their innovation spirit in the following engineering areas: aerothermodynamics, health monitoring strategy for THEMIS, very low cost actuators and aerodynamic surfaces, structural/mechanical engineering, smart manufacturing/industrial, cryo-liquid propellant expertise/equipments. Public announcements shall follow pretty soon.

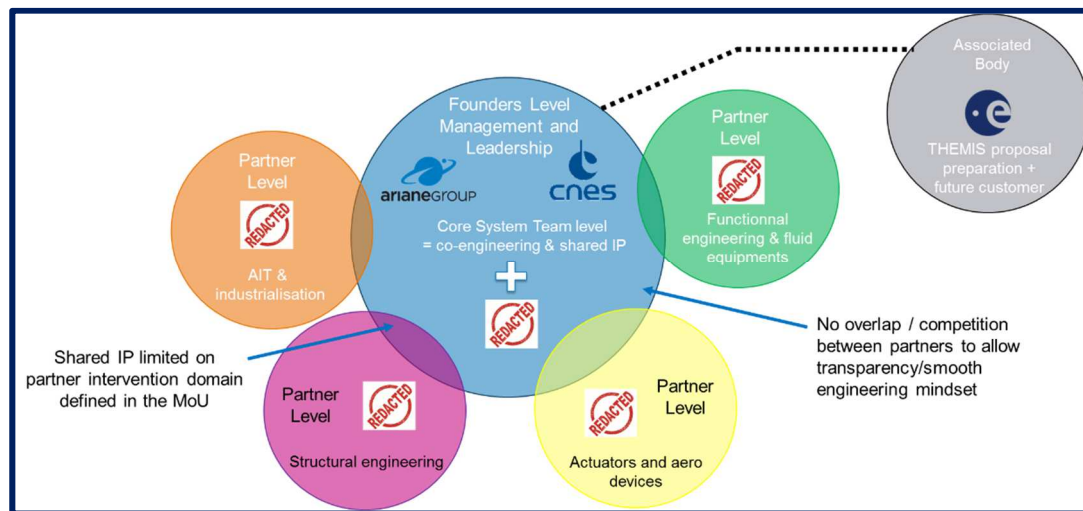


Figure 5 - ArianeWorks set up - T0 + 4 months

Operating somewhat between a start-up or a skunkworks, ArianeWorks is an original public/private partnership made for tackling technical challenges. Two keywords outline ArianeWorks missions, Fast-Tracker and Pathfinder. Fast-Tracker because space activities are growing spectacularly, but also quickly evolving, requiring more than ever swift adaption of space access solutions. The time needed for fielding operational projects, from ideas to launch pad, shall be drastically reduced, and built more and more through iterative design/testing. Spurring more proactively innovation and smart ideas in next generations of Space Access solutions is also a stringent requirement. Keyword here is Pathfinder, as ArianeWorks is a flexible and agile setup with shortened and knowledgeable decision making chain, possibly enabling a more dynamic “rocket ecosystem” in Europe.

ArianeWorks has been inaugurated in presence of French Research Minister Frederique Vidal, and has been hard at work since then, operating for about 4 months ago. The first period has been devoted to initiate a first wave of “proof of concept” actions (see below). 4 topics have been started as a result, and the team is now focusing on baselining “iteration 0” of THEMIS down to subsystem level.

Some figures:

- Headcount: 13 (+ partner’s workforce, here not included)
- Rocket science cumulated experience in the team: > 200 years
- Autonomous budget for first year : ~1 M€ on top of manpower allocated to the platform
- 8 working days to conclude first prototyping contract

3.2 Agile or agile-like development logic

“Agile” is not a magic word that all of a sudden transform your 5 year’s marathon development to a 3 year’s sprint. It is not relevant in any situation, nor does it translate very easily from the software industry – where it is the norm – to a highly sophisticated hardware industry like space rocketry. Fortunately, a set of favourable conditions met with THEMIS call for an adapted or agile-like development logic:

- Ariane NEXT, which is the notional end-product beyond THEMIS, is what we could name a *moving target*: technology mix, engineering requirements or even size/class is far from frozen. Under these circumstances, high adaptability of development logic along the road is a must: final design for THEMIS has to be an iterative process, combining experimental knowledge gained in early steps with Ariane NEXT pictures as they will get clearer and clearer.
- This is just de demonstrator project, not committed to success: (management) failure is here definitely part of the learning process, and we can afford testing approaches that are believed to bring more values without having to formally prove it beforehand. Reverting to classical development logic is always an option.
- Last but not least, as in many space programs, programmatic slicing will be likely on THEMIS. In such conditions, it is far more effective (in terms of value for money) to allocate intermediate hardware milestones to each budget slice, rather than, say, propose to do only engineering paperwork in slice 1 and postpone hardware to slice 2.

The overall change is easily illustrated by the figure below.

First line is typical approach for most of our V-cycle space projects, where final requirements are perfectly known and functional analysis allows to subdivide the global complexity in less complex projects down to the deepest level. Drawback is that, first you have to perfectly specify your final target from Day 1, second, that you won’t practice the “user experience” of the final product before the very last steps of the development process.

Second line speaks for itself: intermediate products are delivered along the development, not perfect nor fully suitable, but bringing value that allow to refine or invent the final end-product through experiments.

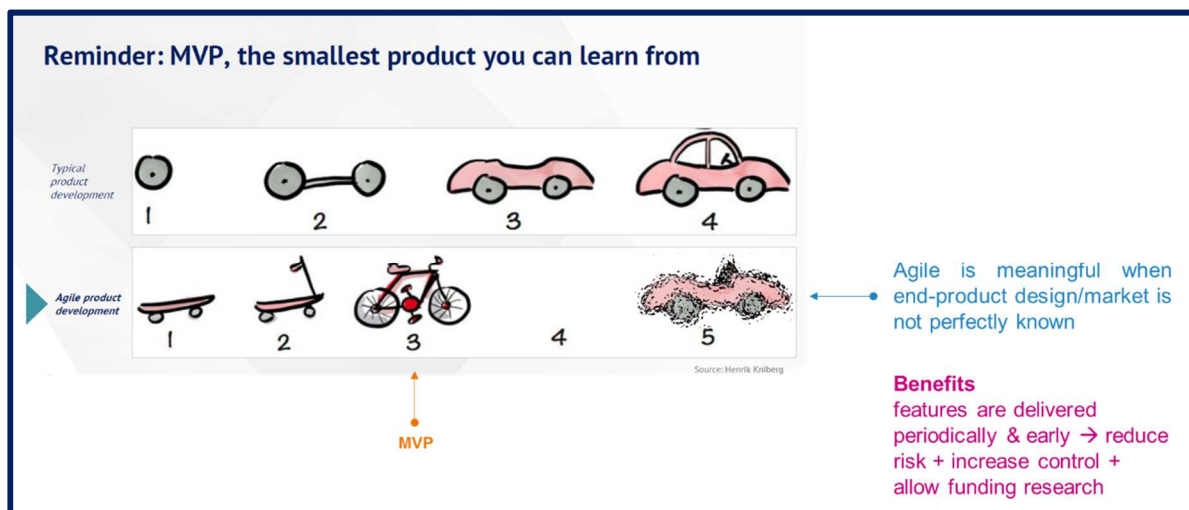


Figure 6 - MVP/Agile approach in the books

Having this in mind, but also having sorted out a classical functional analysis for THEMIS (and ranking associated difficulty levels), the development logic has been reshuffled and is now structured around system level hardware testing foreseen each year, from 2020 to 2024:

- THEMIS-0, or T0 (“0 engine”), will be just a simple tank, where test objectives will focus on modular structural parts, on CH₄ functional characterisation (e.g. thermal stratification, fill/drain procedures, design of ground/launcher fluidic interface), or on avionics (e.g. wireless communications)

- THEMIS-1G (for Ground), will be equipped with the first PROMETHEUS engine M1 as soon as it is made available for more complex test objectives, including of course operating and firing sequence of the engine, throttling or health monitoring with the engine controller (REEC equipment) ...etc.
- THEMIS-1H (for Hop), will add complexity by performing very low altitude take off / landing loops, allowing to approach some ground effects during landing phase, some of the GNC parameters, ground/board targeting strategy...
- THEMIS-3, finally, shall be capable of performing the full flight envelope. Actually, it may even happen that several increment of THEMIS-3 are proposed, as some optimization required for Ariane NEXT (e.g. mass optimization) are not mandatory for just exploring the flight domain. Objectives may be allocated here and there at this stage.

THEMIS 0 and 1 are currently envisaged in France and/or at SSC/Kiruna (feasibility study is already on-going). THEMIS-3 shall ultimately fly from European Spaceport in French Guyana.

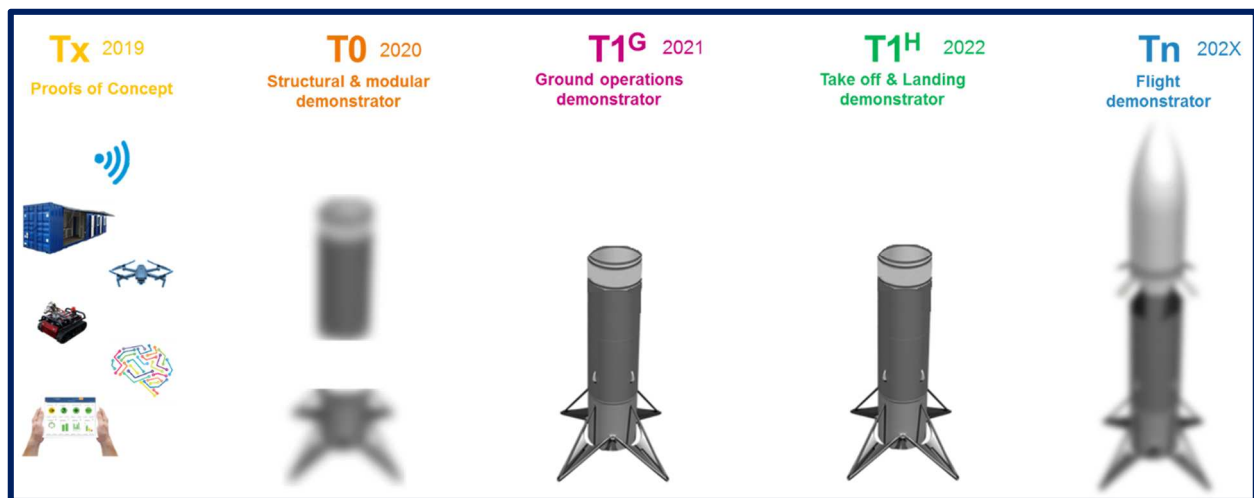


Figure 7 - MVP/Agile approach as proposed to THEMIS development – again, these are not CAD engineering models

3.3 Trying to shortcut TRL ramp up with Proof Of Concept

First 3 months in ArianeWorks were devoted to define meaningful actions on options with strong potential for THEMIS, but that would not be mature enough by aerospace engineering standards. “Proof of Concept” is meant here to provide more than just an elementary technological task, but rather a sub-system or system-level demonstration that would enable an acceleration in decision-making.

As an illustration of the mindset outlined above, one could imagine to involve flying inspection drones in the operational concept / health-check strategy for THEMIS in-between launches (similar to what companies like DONECLE are proposing for aircraft). Should this idea be selected, a typical “first proof of concept” activity could be to simply fly drone with optical measurements devices around the Ariane 5 mock up standing in Le Bourget and on the similar one in Toulouse Cité de l’Espace, and demonstrate that the drone adequately caught the differences. This would of course not be representative of full requirements for a real mission around a rocket (ATEX class security operations, tropical-hardened electronics...etc.) but still provide a valuable end-to-end assessment of “user experience” for this idea and hence help reaching a quick decision. This is the kind of actions that are currently undertaken.

With this mindset, scouting of opportunities was organized for this first wave of activities by mapping predefined “interesting engineering needs” related to THEMIS (e.g. rapid mechatronics prototyping, predictive maintenance) together with overall trends in Deep Tech non space fields (e.g. automotive, artificial intelligence). “non-space” was here a prerequisite: companies relevant but already close to Ariane ecosystem were not the one targeted at first. These are indeed most likely to be involved within existing R&D programs and boarding them in THEMIS will be relatively easy. Actually, this is already an ongoing process thanks to close coordination between ArianeWorks and CNES/ArianeGroup backoffices (e.g. CH4 lightweight electric pumps, cryocomposite materials). The vision was instead to try to activate with this initiative fresh ideas / fresh blood that for some reasons would not be easy to connect by existing CNES or ArianeGroup channels.

For this purpose, *Hello Tomorrow*, which is animating a worldwide survey network in Deeptech, provided support to ArianeWorks at several levels:

- Formalizing our expectations, both in technical perimeter and in a "minimum valuable product" approach that would be within reach of small non space actors. This simplification/formulation effort was absolutely necessary not to discard potential,
- Scouting relevant actors, organizing contact and then sorting out, ranking the 60+ opportunities that the team got in interaction with in that timeframe,
- Coaching in the deployment of actions towards start-up / SMEs, keeping this relation with an agile mindset, featuring co-engineering, progressive complexity build-up...etc. rather than just a contract on a set of hard requirements.



Figure 8 - Some highlights of ArianeWorks first 4 months

Actions selected in the first wave address the following areas:

- **Landing pad concept** featuring a design that could simplify rocket architecture wrt landing phase.

We cannot (regretfully) be very explicit on this topic right now, as first this is still in early stage testing and second intellectual property is not secured yet. What can be shared is that the “proof of concept” acceleration effort consisted in prototyping the full concept at small scale (about 1/10th of real size). This has been performed between March and July 2019, opening the possibility to end-to-end test the idea with the FROG vehicle after the summer.

- **Wireless industrial-grade avionics**, with the vision to avoid physical electrical connexions for ground/board communications during pre-launch and landing phases, and eventually to design THEMIS with much less harness than standard rockets (cost saving, mass saving, architecture flexibility).

With this objective in sight, actions initiated deal with two technologies considered in the automotive industry, both for data connexion and power transmission. Progressive testing plan has been elaborated (e.g. dynamic network, robust bandwidth, cybersecurity), hopefully allowing to reach in 2019 a decision milestone on this technology, which had been evaluated for years in Ariane R&D programs without reaching conclusion so far.

- **Safe distant operations** - relying on robotic capabilities are under consideration for performing early operations on landing zone, simplifying security management and related equipment needs.

The action was co-initiated with Callisto project, which could premier the use of robot for inspection or restoring physical fluid connexions during post-landing operations. Proof of concept will start here with simple connexion scenarios, and progressively add more complex tests with real geometry, multiple connectors type, fluid transfer, ATEX requirements, autonomy features...etc.

- **Predictive maintenance** - objective here is to possibly embark artificial intelligence algorithm in post launch diagnosis strategy for Themis.

First elementary action is underway, and is a simple test by an awarded specialized start-up on a real Ariane piece of hardware that undergone heavy testing history.

All of these are in progress, next to other ideas being prepared for next wave, such as low cost hot thermal protection, alternated tank structural part manufacturing or full internal piping/fluid architecture.

4. THEMIS use cases: illustrating the “multipurpose” value of the project

As was explained in chapter 1.2, the value of THEMIS lies on its strategic flexibility for Europe, accelerating key technologies and system demonstration that may eventually turn operational in different formats, architecture or missions. Even beyond its Ariane NEXT main purpose. Two obvious examples of this capability have been evaluated in parallel to THEMIS development: reusable microgravity platform and cost-optimized microlauncher.

THEMIS Flight Demonstrator with 3 engines is actually pretty close to a **sounding rocket** for what concerns flight performance, potentially allowing 500 km / 500 kg rides in reusable mode. Should such option be pursued, this would offer several advantages for commercial suborbital flights:

- Cheap launch as the THEMIS Flight Demonstrator(s) and corresponding ground infrastructure would be used at first, rather than requiring new investment,
- Payload(s) mass and volume domains will be very large, in comparison to existing sounding rocket offer,
- Microgravity duration would be pretty long (several minutes),
- Recovery of the payload will be smooth (if not deployed during the flight),
- The vehicle could provide high velocities for aerodynamic vehicle demonstration (Mach 6 to 8).

THEMIS Flight demonstrator could be a great opportunity for institutional, commercial and educational suborbital/microgravity applications. This is an option that will deserve a specific attention as the project will progress.

Microlaunch, on the other hand is a tricky market. Competition is fierce (competing microlaunchers and rideshare solutions), small satellites market presents many uncertainties, is limited in size and its growth remains all but certain as recent analysis have stressed. Focus here is clearly on cost and business model for launchers. Much more than on technical challenges.

In this context THEMIS opens interesting options, with very different business model than the bulk of 100 microlaunch projects currently in the air. One can easily figure out that THEMIS-1 (single engine) is a decent microlaunch expendable first stage when topped with a modest upper stage, while THEMIS-3 (3 engine variants) would be capable of addressing microlaunch market in reusable mode when associated to a more powerful upper stage. Depending on variant and flight mode, this would offer scenarios for flying 200 kg to > 500 kg payloads. Once this is understood, most interesting aspect lies in business model:

- Low CAPEX, as most risky and costly part of the development (namely: reusable first stage + ground infrastructure) would come out of the THEMIS development effort undertaken for Ariane NEXT
- Robust OPEX, as economical balance would be sought not on the sole microlaunch segment, but spread over other uses of the PROMETHEUS and THEMIS production lines for Ariane NEXT. Flying 50 rockets a year is not necessary to drive launch cost down in this situation.
- Flexible in front of uncertain markets, as scale-up is a natural built-in feature of THEMIS, and reusability feature would add options for tuning cost/performance against sweet spots that are still questionable today.

All of this draw an interesting picture and value proposal, pretty different from past ventures in that field that CNES or ArianeGroup may have experienced, and from current known projects.

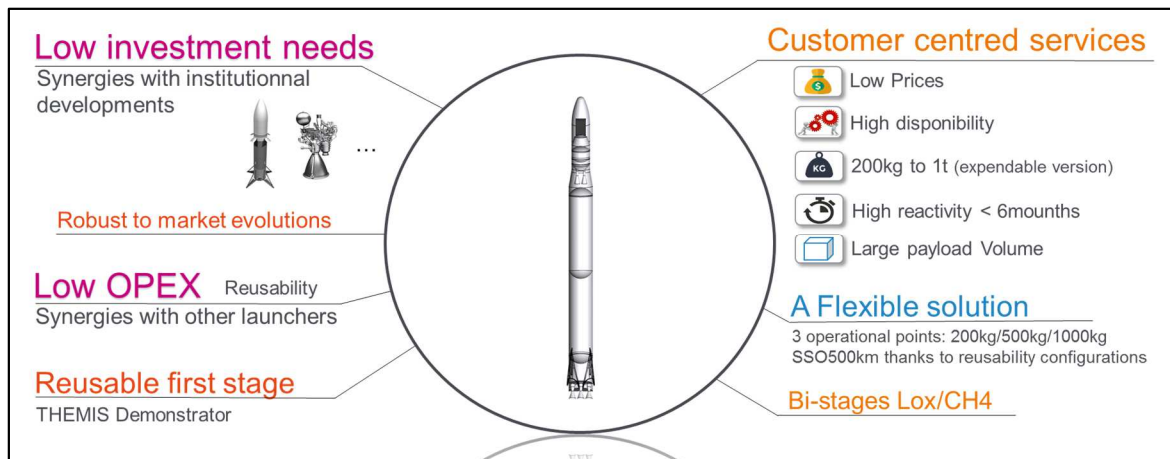


Figure 9 – THEMIS derived Microlauncher Value proposition

5. Conclusion

Following earlier important moves undertaken with PROMETHEUS and CALLISTO, THEMIS low cost and reusable precursor is the logical next step along European future rockets roadmap, setting the only pragmatic path for halving space access costs during next decade. In that regard, rocket reusability feature should not be viewed as an objective *per se* but as a lever serving the strategic goal of cheaper space rides.

Technological challenge is not only at stakes here, as evolving space activities require an increased tempo and thus, innovation in management for driving THEMIS project at a meaningful pace. This shared vision led CNES and ArianeGroup to join forces for creating ArianeWorks, a dedicated and original unit tasked precisely with this objective. Started 4 months ago, the innovation platform is progressively ramping up, working closely with ESA, boarding in key partners, and giving shape to THEMIS accelerated project.

Overall system picture has been outlined in past months, narrowing inputs required to move forward (trajectory, overall sizing and loading, technology requirements...etc.). Meanwhile, development logic was reshuffled so as to propose early hardware testing and enter as soon as possible in test/learn/improve cycles. Finally, specific “proof of concept” actions were sparked in selected areas to offer a fast-track decision path for – hopefully – bringing bold and impacting innovations within THEMIS design by 2023.

Aligning strategic projects, joining forces and running fast has been key in Ariane success story 40 years ago. This cocktail is more than ever relevant for upcoming space challenges in Europe, and this is what THEMIS and ArianeWorks are about.

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