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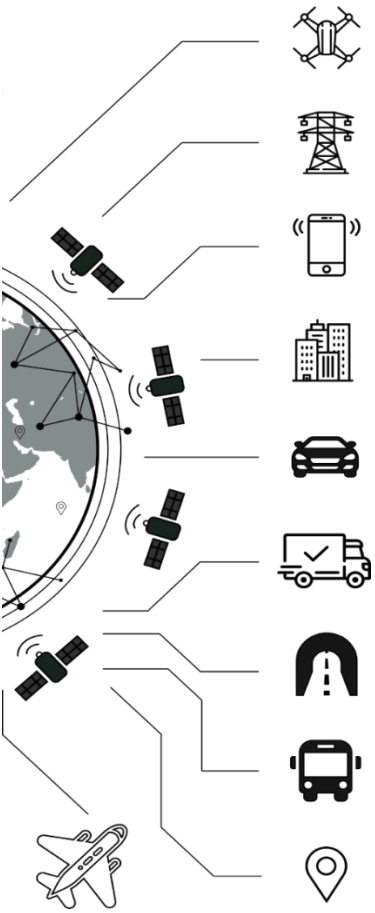
Assessment of Effectiveness of NAVISP Phase 1 & 2 and Recommendations for Phase 3

A report by the NAVISP Advisory Committee (NAVAC)

Assessment of Effectiveness of NAVISP Phase 1&2 and Recommendations for Phase 3



Navigation **I**nnovation and

Support Programme

Advisory **C**ommittee (NAVAC)

March 2022

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Executive Summary

Three years after our previous report on the NAVISP effectiveness, NAVAC has undertaken again the task of assessing its performance. And by all measures, our conclusion is that the Programme is still doing well. We now have much larger evidence on which we can work than back in 2019. More than € 100 million have been allocated to the almost 200 activities funded by NAVISP since its launch, out of which the industry has completed 46, distributed across its three Elements. The Programme is running at full speed and delivering.

We should not linger though on the bright perspective that NAVISP displays at glance. Our assessment has targeted to spot what we are doing well, and should keep doing, and what we are doing wrong, or not doing at all, and could be done for the programmme's benefit. Once again, we have tried to provide constructive criticism to the Executive in the quest for enhancing its achievements.

The Committee regards highly the accomplishments made this far. NAVISP has proven to be a powerful innovation engine, able to attract a wide range of actors along the PNT value chain. Besides, it has managed to cover a broad spectrum of technologies beyond GNSS, as always was its objective. The programme has been very successful in engaging newcomers to space, which enables cross-fertilization between different industries and technologies. However, the focus is still too much on mitigating technology risks. We are still somewhat missing the “wiring” that we called for in our 2019 report.

We have found out that companies are using the program to fund "high risk investments" in technology rather than to improve the competitiveness of existing products. This is neither good nor bad, but speaks loudly about industry priorities: the European industry does not seem very concerned about catching up with international competitors, even in highly profitable segments of the market (e.g. consumer market), but rather with capturing future potential "blue oceans". Market and regulatory risk mitigation still takes a small share of the funding for what we would expect. We believe that the programme needs some adjustment in this respect.

While we fully endorse the objective of broadening the scope of technologies considered within the programme, we think that ESA must not forget its space heritage. ESA can convene the skills, technical expertise, industry partners, and Member State delegations in a way no other organization can. NAVISP should enhance its role in preparing the way towards future innovative satellite navigation systems in concert with EGNSS evolutions, as it does in fostering key technology developments to sustain the European competitiveness in the PNT field.

We have concluded that the programme efficiency has improved since 2019 by all key indicators. Maintaining attractiveness is a permanent endeavor, though, and a tough one when you are trying to catch the attention of new players, especially if they are large fishes in their own bowl. ESA has done a lot to streamline its internal processes to ease the work of new entrants, but ESA cannot do it alone. The support of the Participating States by simplifying their internal processes as far as possible will help further enhancing NAVISP efficiency.

There is also room for improvement in outreach actions. On the one hand, NAVISP should take advantage of the new Galileo services to increase its outreach in professional markets. On the other hand, taking joint actions with other public bodies, industry associations, or institutions, will raise the

awareness about NAVISP potential to fund actions concerning areas presently underrepresented in the programme, e.g., mitigation of regulatory risks.

The overarching theme of this report is that NAVISP pays back. The investment made this far has helped a good number of European companies to develop technologies, mature new products, address new markets and support strategic national initiatives. It has created new jobs and increased the wealth of knowledge in the PNT domain. The programme can already boast quite a few success stories, and there will be more to come as industry completes ongoing projects. We at NAVAC believe that NAVISP is meeting its objective and encourage ESA to pursue this undertaking by launching a new programme Phase.

1. Introduction

1.1. The NAVISP Advisory Committee (NAVAC)

The Navigation Innovation and Support Programme Advisory Committee (NAVAC) is a committee of senior external experts established in October 2018 by the European Space Agency Director of Navigation to provide an independent advice on the objectives, strategy, and relevant technological priorities of NAVISP.

Members are appointed for an initial period of 2 years. The current members of NAVAC are:

Luis Mayo	Chairman of NAVAC since 2020, former CEO of Tecnobit and Grupo GMV
Roger McKinlay	Director for Quantum technologies at Innovate UK government agency and chairman of NAVAC from 2018 to 2020
Bernd Eisfeller	Former Director of the Institute of Space Technology and Applications of the Universität der Bundeswehr and member of the DLR Program Board for Communication and Navigation.
Peter Grognard	Managing Director of the Von Karman Institute for Fluid Dynamics and founder and former manager of Septentrio
Didier Faivre	Former Director of Centre Spatial Guyanais and Director of Navigation at ESA

The main tasks of the Committee are to advise and/or make recommendations on:

- Thematic areas for the development of NAVISP activities;
- Proposals for the development in NAVISP Element 1;
- Support required to enhance the Programme effectiveness.

More specifically, on request, these tasks include to:

- provide recommendations as to which broad areas of interest have the greatest potential for the development of NAVISP activities and how this potential may best be realized;
- make a preliminary assessment of ideas and proposals made by the Agency on NAVISP Element 1 Workplans, in order to assist NAVISP management in setting priorities;
- provide ad-hoc advice on the results and value of individual projects;
- make an overall assessment of the Programme effectiveness at the end of each phase and make recommendations for the following one.

In June 2019, NAVAC completed an assessment of the effectiveness of NAVISP Phase 1 and issued a number of recommendations for NAVISP Phase 2[1], which was at that moment being proposed for decision at the end of 2019 and subsequently approved. The duration of NAVISP Phase 1 extends over 5 years, from the start of the programme in 2017 to end of 2021. The duration of NAVISP Phase 2 is 3 years, from 2020 to end of 2022, partially overlapping with Phase 1.

In view of preparing the proposal to continue the programme beyond end of 2022, NAVAC has been invited to assess the outcomes of the first two phases of the programme and issue recommendations for a new phase of NAVISP: Phase 3. In doing so, due account is taken of the results of the 2019 assessment.

1.2. Outcomes of NAVAC 2019 Assessment

NAVAC evaluation of the programme in 2019 was very positive. In the light of the status of the programme at that time, NAVAC concluded that NAVISP was a successful and valuable instrument for enhancing the competitiveness of the European industry in the PNT domain and that it should be continued in a Phase 2 with strong support from Member States. The key findings and recommendations of the 2019 report are provided in Table 1 and Table 2.

The key findings broadly confirmed that the initial ambitions of the Programme were being realized. Areas for improvement were also identified, namely the need to reinforce the addressing of new markets, to encourage more activities aiming to reduce market and regulatory risks, to involve in the programme the key European non-space PNT system integrators, to further streamline procurement processes and to encourage cross-fertilization across national projects.

Key Findings (2019 Report)	
ID	**Description**
1	The non-GNSS centric approach of NAVISP is one of its strongest assets and is leading the way to innovation.
2	The scope of the Programme is appealing and aligned with industry needs.
3	The Programme has succeeded in putting together a broad portfolio of innovative activities with strong focus on technology push and less than desirable focus on market pull.
4	Phase 1 of the Programme has succeeded in addressing a broad variety of PNT sectors but effort is not fully coherent with the European industry market positions.
5	Exploration of new markets in Element 2 can be further enhanced.
6	The Programme has fostered the participation of new SME entrants, and business networks, however engaging large non-space primes is still a challenge.
7	The management objectives of the Programme have been broadly met contributing to a positive reception by industry and a further appetite for simplification of administrative procedures.
8	Element 3 has been an adequate mechanism to accommodate activities of national interest in a wider multi-national programme. This opens opportunities for cross-fertilization between activities.

Table 1: List of Key Findings in the 2019 Report

The recommendations were addressed both to ESA and the NAVISP participating states and included advice on prioritization of activities in terms of scope and budget, continuing the outreach efforts with

[1] "Assessment of Effectiveness of NAVISP Phase 1 and Recommendations for Phase 2", June 2019, https://navisp.esa.int/uploads/files/documents/5d78ce40eda8e266575831.pdf

special focus on the areas for improvement, further simplify the procurement process and use Element 3 as a forum to exchange common experiences across national projects.

Recommendations (2019 Report)	
ID	**Description**
1	To maintain and if possible widen the non-GNSS centric view of NAVISP with the objective to enhance the robustness of the user's position, navigation and time determination. This could be achieved by: ○ Element 1: maintaining a high percentage of the work plan budget devoted to R&D on non-GNSS centric activities. ○ Element 2: organizing dedicated calls to non-GNSS centric activities Examples of non-GNSS centric activities include the development of multi-sensor PNT solutions where GNSS is not the main sensor, e.g. image and terrain-based navigation and in general any activity aiming to mitigate the vulnerability of GNSS to jamming and spoofing.
2	ESA to encourage the participation of a wider number of member states to Element 1 due to the positive effects on competition.
3	To retain the current structure of NAVISP focusing on innovation, competitiveness and national strategies since it fits the general interest and affinities of the stakeholders in the Programme.
4	ESA is encouraged to monitor the capability of Element 1 to generate follow-on industrial initiatives in the PNT sector.
5	ESA to include in Element 1 Workplans more activities aimed to reduce regulatory risk related with the introduction of existing PNT technologies in new markets/domains. Proof-of-Concept or demonstration activities would go in this direction
6	ESA and participating states to encourage the submission of proposals to Element 2 aiming to reduce market risks by strengthening the requirements on industrial/product maturity of the outputs of the activities.
7	To stress in the various outreach actions of ESA on the Programme, the opportunities that NAVISP offers to reduce market and regulatory risks and not only technical risks.
8	ESA and the participating States are encouraged to discuss with non-space European key players in the GNSS/PNT markets in order to understand how to make the Programme more appealing to their participation.
9	To organize within Element 2 a dedicated call addressed to specific PNT sectors currently underrepresented or of strategic significance.
10	To encourage the exploration of new markets in Element 2 by organizing a dedicated call addressing the introduction of existing PNT technologies in new markets.
11	ESA and the participating States are encouraged to discuss with system integrators (primes) that are entering in the PNT market but whose primary business is not space related, about the opportunities that NAVISP may offer to their activities.
12	Participating States to Element 2 are encouraged to consider to increase the budget per activity in order to increase the effectiveness of the public investment allowing projects to arrive to more mature outputs from the industrial product point of view.
13	ESA to consider the inclusion of mechanisms in the Element 2 current procurement process allowing to better control the time taken by companies to prepare full proposals and the time to obtain the required letter of support.
14	ESA is encouraged to continue its networking efforts and in particular the regular organization of NAVISP industry days were stakeholder in the Programme could meet and share experiences and results.
15	ESA to consider, within the limits of due diligence, further simplification of the procurement process to allow reducing even further the time required to place contacts in Element 2, in particular, for those activities where the main focus is to reduce the market risk.
16	ESA is encouraged to promote cross-fertilization among Element 3 activities by for example, organizing workshops on common topics.

Table 2: List of Recommendations in the 2019 Report

1.3. Scope and Contents of the Document

The scope of this document is to present the results of the assessment by NAVAC of the NAVISP Phase 1 and Phase 2 and to provide recommendations for a continuation of the programme in a NAVISP Phase 3.

The status of the programme is briefly recalled in Section 2, followed by an assessment of the activities in Section 3 taking a similar approach to the one adopted for the 2019 report. Section 4 contains the results of a consultation with the industry participants in Element 2 of the programme both for on-going as well as completed activities. The analysis of lessons learned from completed activities was not possible in the 2019 report as at that time, only a few activities had been concluded. More in detail, the success stories for completed activities in Element 1, 2 and 3 of the programme are described in Section 5. Section 6 focuses on an analysis of the efficiency of the implementation of the programme looking at the several KPI's involved in the procurement cycle of the activities. Section 7 is the main section of this document, containing the key findings and recommendations of the Committee in the light of the contents of the previous section. Finally, the overall conclusions are presented in section 8.

The report is complemented with a number of annexes recalling the definitions used in the assessment, the details of the industry online questionnaire, the criteria adopted to classify Element 2 activities and products as well as the list of key findings and recommendations of this report.

2. NAVISP Status

2.1. Recall of NAVISP Objectives

The main NAVISP objective is to facilitate the generation of Satellite Navigation/PNT innovative propositions with participating States and their industry, in coordination with the EU and its institutions.

NAVISP is an important element for the overall European GNSS landscape, capable of leveraging both ESA expertise gained through the Galileo, EGNOS and other related navigation programmes and the existing industrial base of the European Navigation sector.

It aims to support European industry in succeeding in the highly competitive and rapidly-evolving global market for Satellite Navigation, and more broadly PNT technologies and services while supporting participating States in achieving their national objectives and enhancing their capabilities in the sector. The following is the understanding by NAVAC of the NAVISP objectives:

1. Addressing the end-to-end PNT value chain with a view to enhancing Member States industrial capabilities in Satellite Navigation while stimulating jobs and growth in the space sector;
2. Supporting the industry of the participating states to mature the technology readiness of the products from established companies and also encourage new entrants into the PNT market;
3. Mitigating the relevant risks, namely:
    - **Technology risks** including technology readiness; performance levels and/or QoS (Quality of Service); ability to compete long-term; and ability to integrate with non-space technologies
    - **Market and Business risks** including barriers to commercial success; the maturity of new business models with high-risk/high-potential returns; and the ability of companies to implement such models
    - **Regulatory risks** including regulations as barriers to market entry; regulations as barriers to new suppliers; and regulations favouring incumbent suppliers
4. Supporting PNT national programmes and relevant institutional activities following ad hoc participant Member States' requests.

NAVISP does not duplicate nor change the basis on which the strategy and approach to R&D related to the evolution of the Galileo and EGNOS systems is defined. This is determined and controlled through well-established mechanisms in the EU.

2.2. Programme Implementation Status

At the time of compiling the data of this report (July 2021), NAVISP has invested around €100 million in the approximately 200 activities supported. A total of 46 activities have already been completed. Under Element 1, 21 activities have been completed, Element 2 includes 23 completed activities and under Element 3, 2 activities have been completed. The total funds spent on elements 1, 2, and 3 by

type of organization are shown in Figure 1. About 42% of the general funds are dedicated to SMEs, followed by large companies, research institutions, and governmental agencies (the latter one only counts for Element 3). Element 2 receives and offers the most funding, followed by elements 1 and 3.

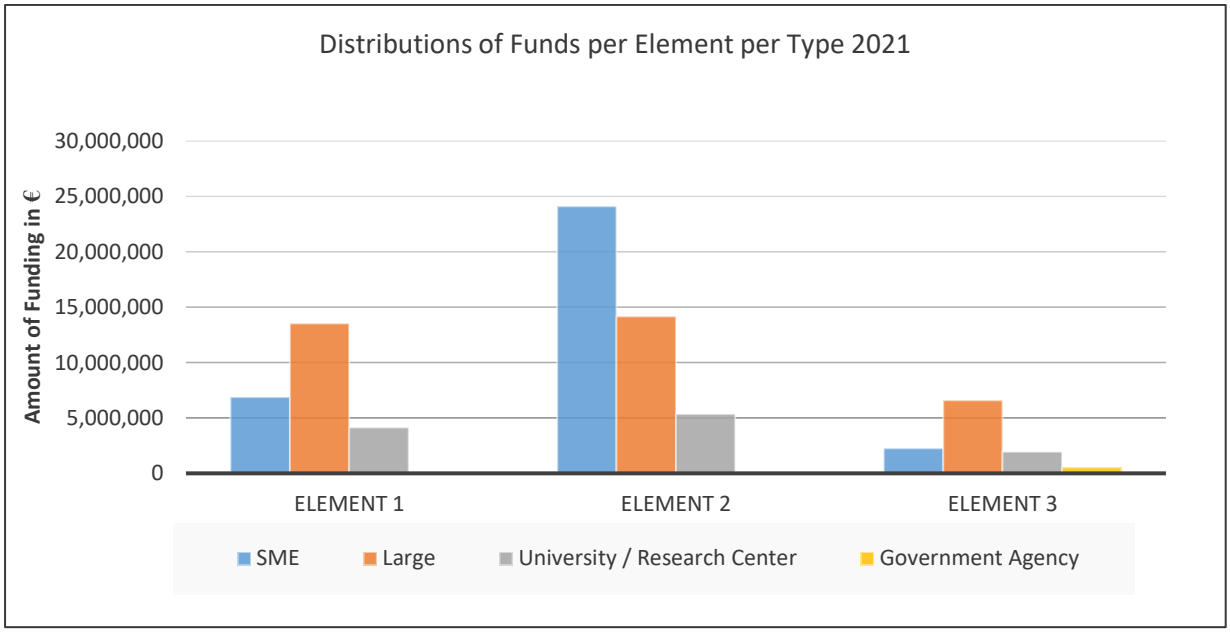


Figure 1: Distribution of Funds per Element

3. Assessment of NAVISP Activities

The NAVAC members have assessed the distribution of funding of the activities contained in Element 1, 2 and 3 from 2017 to 2021 against the criteria applied in the 2019 analysis:

- Funding by Objectives
- Funding by Innovation Category
- Funding by Risk Mitigation

The first category aims to assess how much funding was distributed according to the objective of each activity. For this purpose, different objective categories were formed depending on the Element being assessed. The Innovation Category is the same for all three Elements and assesses whether an activity has a high innovation potential or rather a low one, depending on the degree of novelty and the targeted market. The Risk Mitigation category is divided into technological, market, and regulatory risks and helps to determine which risk is dominantly mitigated in each activity.

In addition, the evaluation of each Element was adjusted and expanded as needed. For example, the evaluation of the distribution of funding for element 2 was expanded to include the funding for markets, products, and challenges in a more detailed than in the 2019 report. A closer definition and a list of indicators can be found in ANNEX A.

The temporal window of the activities covered in the 2019 report spanned from the start of the programme in January 2017 till February 2019. In this report, the temporal window of activities spans the entire period since the start of the programme, that is from January 2017 till the time of closing of this assessment (July 2021).

3.1. Element 1

Element 1 activities have been evaluated based on the funding by objectives, innovation category and risk mitigation. These categories were used by the NAVAC members to assess the distribution of funding from 2017 to today. Overall, 68 activities have been considered for the following assessment, representing a total budget of 30.496 K€. The results of the evaluation of Element 1 can be found in the sub-sections below.

3.1.1. Funding by Objectives

The types of activities on which the key objectives in Element 1 are based are:

- Feasibility studies for the emergence of new PNT concepts;
- Contributions to PNT technology innovation;
- Proof-of-Concept and demonstrations of promising PNT-based services and solution

In general terms and within the limits of the budget allocated to Element 1 activities, the first objective covers conceptual studies, the second objective covers technology developments, and the third objective covers demonstrations of complete solutions.

Around the half of the funds (~49 %) are allocated on the development of PNT technology innovations. The remaining funds are almost equally divided between emerging PNT concepts and Proof-of-Concept and demonstrations, with a small difference in favour of the latter category (see Figure 2).

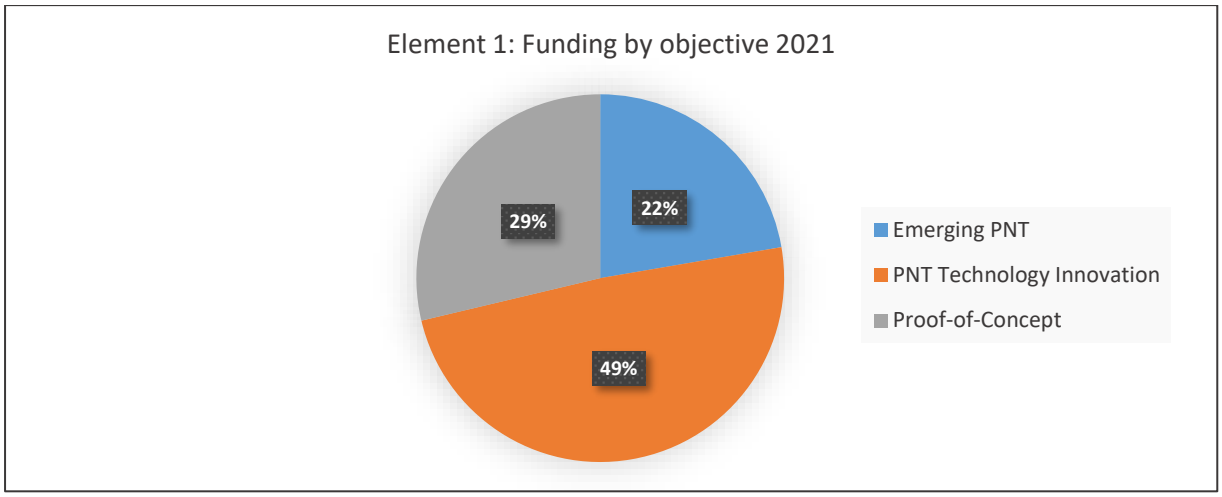


Figure 2: Element 1 Funding by Objective 2021

A comparison of the allocation of funds presented in 2019 shows that when considering the activities initiated as from 2019, the overall allocation of funds to development of PNT technologies has decreased slightly, while proof-of-concepts and demonstrations in particular have increased. Funding for feasibility studies has decreased slightly, by 2% (see Figure 3). This shows that from 2019 a higher emphasis has been put on the demonstration of solutions in line with the NAVAC recommendations.

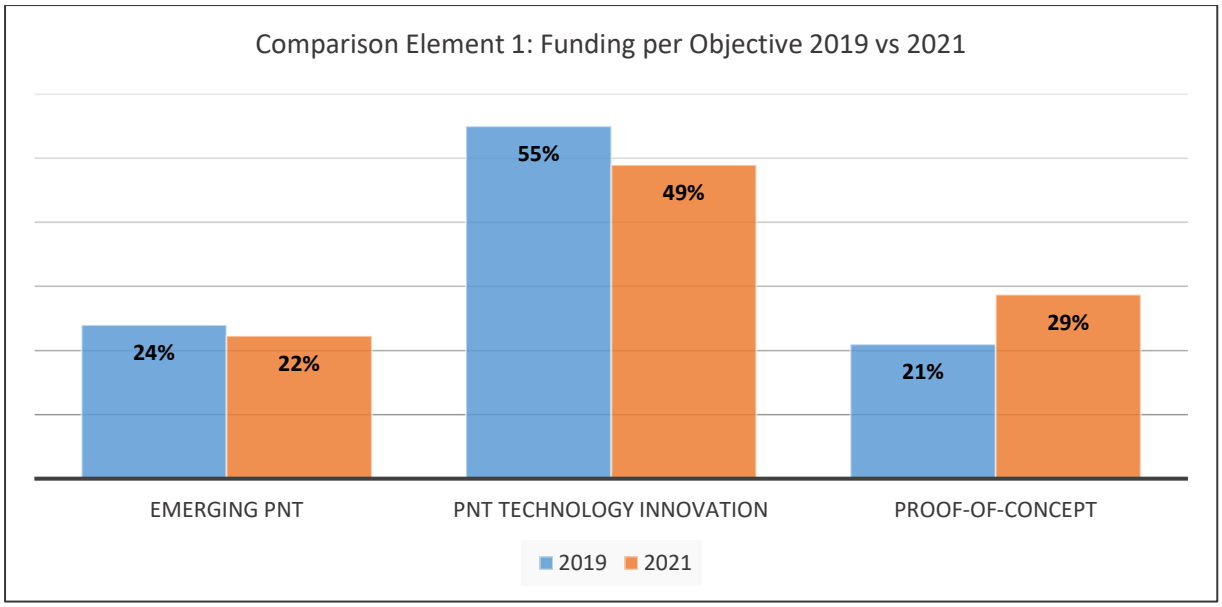


Figure 3: Element 1 Comparison- Funding by Objective

3.1.2. Funding by Innovation Category

The majority of the Element 1 budget is allocated to Innovation Categories 2 and 4, which have the highest technological innovation potential. Around 86% of the funding is thus allocated to activities

involving new techniques or technologies in existing or new markets (see Figure 4). Category 3 includes around 9% of the funds, addressing existing technologies in new markets. Only 5% of the funds are assigned to category 1, the introduction of an already existing technology to an existing market.

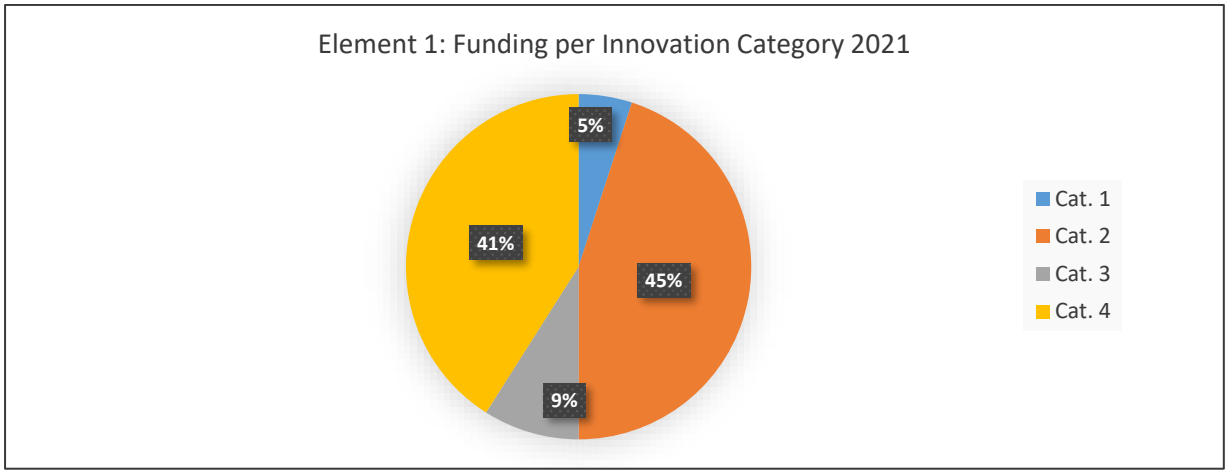


Figure 4: Element 1 Funding per Innovation Category

Compared to the results presented in 2019, funding in categories 1 and 3 has decreased, while funding in categories 2 and 4 has increased. Although this is encouraging, as categories 2 and 4 are considered to have the highest innovation potential, the low allocations of funds in category 3 indicate that the NAVAC recommendations of exploiting the possibilities of addressing new markets with existing PNT technologies[2] have not been fully followed. The development from 2019 to 2021 can be found in Figure 5.

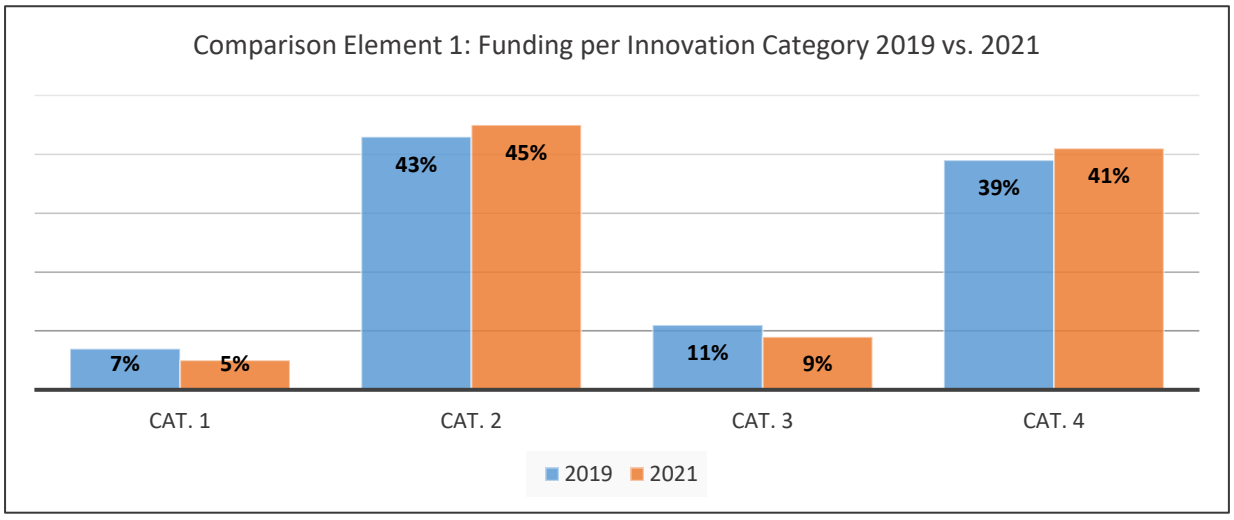


Figure 5: Element 1 Comparison- Funding per Innovation Category

3.1.3. Funding by Risk Area

Looking at the distribution of funds by risk area, technological risks can be identified as dominant. About 85% of the funding is aimed at counteracting technological risks. About 9% of the funds are

[2] REC#5 NAVAC 2019 report

aimed at minimizing market risks and only 6% are associated with regulatory risks (see Figure 6). Since Element 1 is aimed in particular at developing new technological innovations, the distribution of funds reflects the contextual set-up of Element 1.

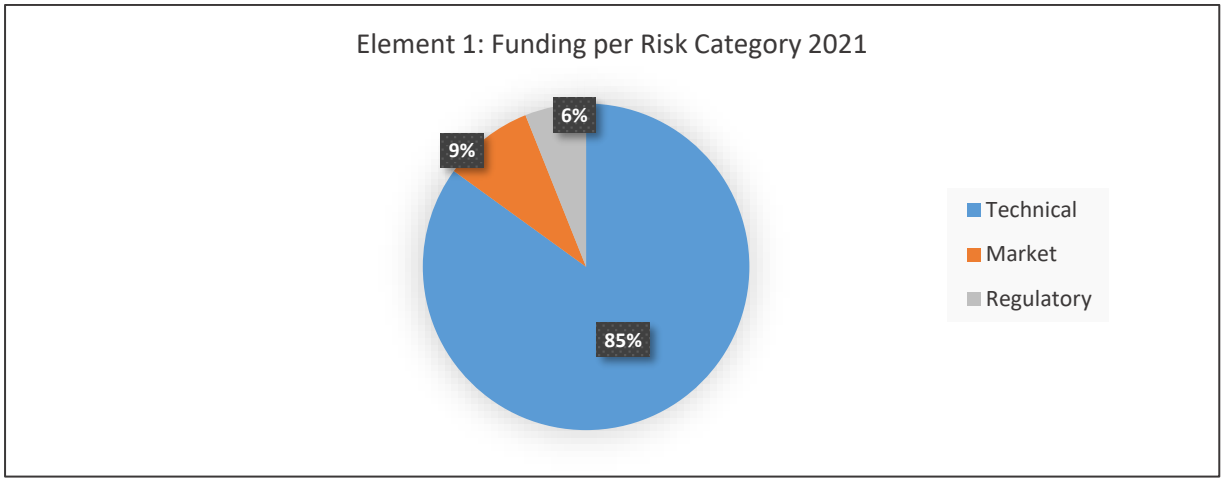


Figure 6: Element 1 Funding per Risk Area

Compared to the results presented in 2019, more funding is allocated for activities targeting technical risks. Funding allocated to mitigation of market and regulatory risks, stays very low and even decreasing in contrast with the previous NAVAC recommendation of paying more attention to the reduction of regulatory risks. This is consistent with the decrease of funds allocated to Innovation Category 3 (see Figure 4).

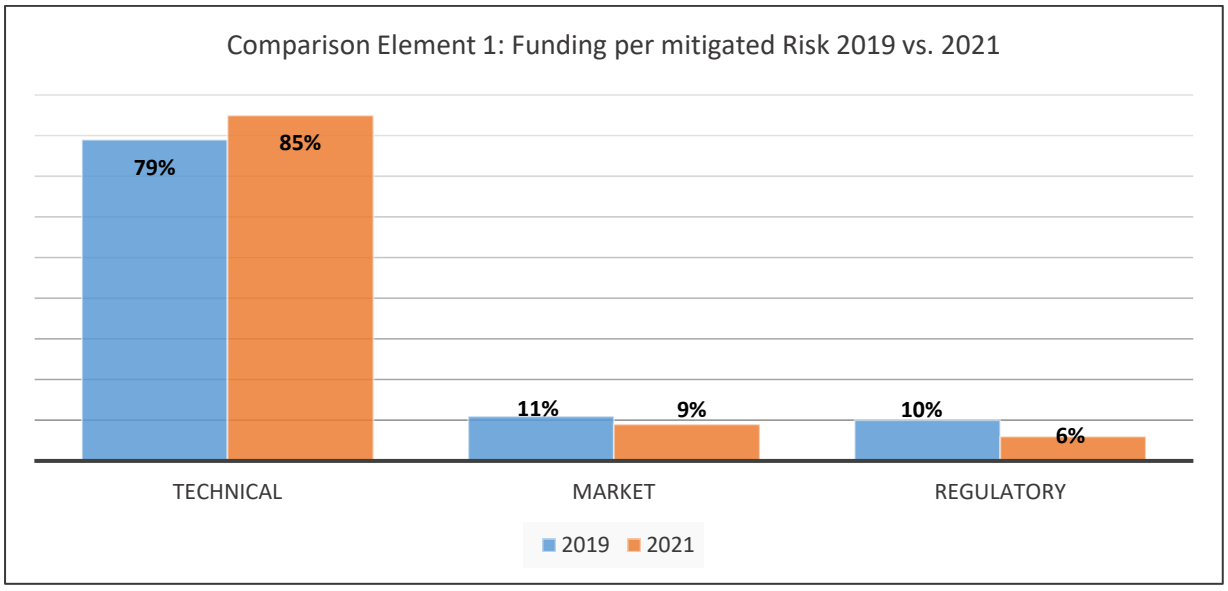


Figure 7: Element 1 Comparison- Funding per Risk Area

3.1.4. Activities not awarded or not reaching the objectives

Since Element 1's main goal is to generate very innovative concepts, techniques, technologies, and systems linked to the PNT sector, there is an implicit risk that activities might not be going in the right direction or achieve the stated objectives. This can happen at any time in the procurement process. The analysis of the Element 1 data shows that, of the activities defined and including the Workplan

2021 this happened on only a very few occasions. As such one activity (less than 2%) did not fully meet its objectives, another activity was not pursued in favor of a similar activity under preparation under another agency programme, and at about the same time, three activities (5%) were advertised as ITTs but no bids were received or the bids were not supported by the participating states. The ITT's canceled, covered indeed very high-risk topics such as the feasibility study of a relativistic PNT system or technology for underwater PNT. Overall, that most of the activities of Element 1 are reaching the objectives defined by the Agency is positive, although it could also be an indication that the objectives of the activities were not ambitious enough considering the high-risk profile which Element 1 should take.

3.1.5. Preliminary Conclusion with Respect to 2019 Assessment

Overall, the trend in Element 1 distribution of funds is considered positive as the activities initiated through the various workplans are characterized by a high level of innovation which is the main purpose of this Element of the programme. A higher emphasis has been also given to proof-of-concept activities which reflects the intent by the ESA Executive to facilitate the transition from Element 1 to Element 2 activities. However the focus of the activities still largely remains on the reduction of technical risks while reduction of market and regulatory risks should not be forgotten as they play an important role in the adoption of novel PNT technologies and solutions. The funding allocated to this type of activities is still relatively low.

3.2. Element 2

Element 2 activities have been evaluated based on the funding by products, markets, challenges/objectives, and innovation category and risk area. The use of additional categories makes it possible to obtain more detailed insights into the nature of the activities and thus to carry out a more precise evaluation based, among other things, on future market and product trends. A definition of the already known and additional categories used for the analysis can be found in Annex A & B. Overall, 109 activities have been considered for the following assessment, representing a total budget of 54.465,41 K€, from which 55% was allocated to SMEs. Element 2, in particular, is characterized by its large number of different actors. Overall, 65% of the primes were SMEs. Moreover, 45% of the actors have never worked with ESA and about 55% of the actors are not part of the space industry, even considering that the definition of space industry used in this report is quite wide[3]. Within Element 2, 26 consortia with at least two different actors (SMEs/large companies/universities and research centers) and 10 international consortia were formed.

[3] The main activity of the large majority of the space industry considered in this report is the space downstream sector, e.g. GNSS receivers, simulators, GNSS solutions, etc…

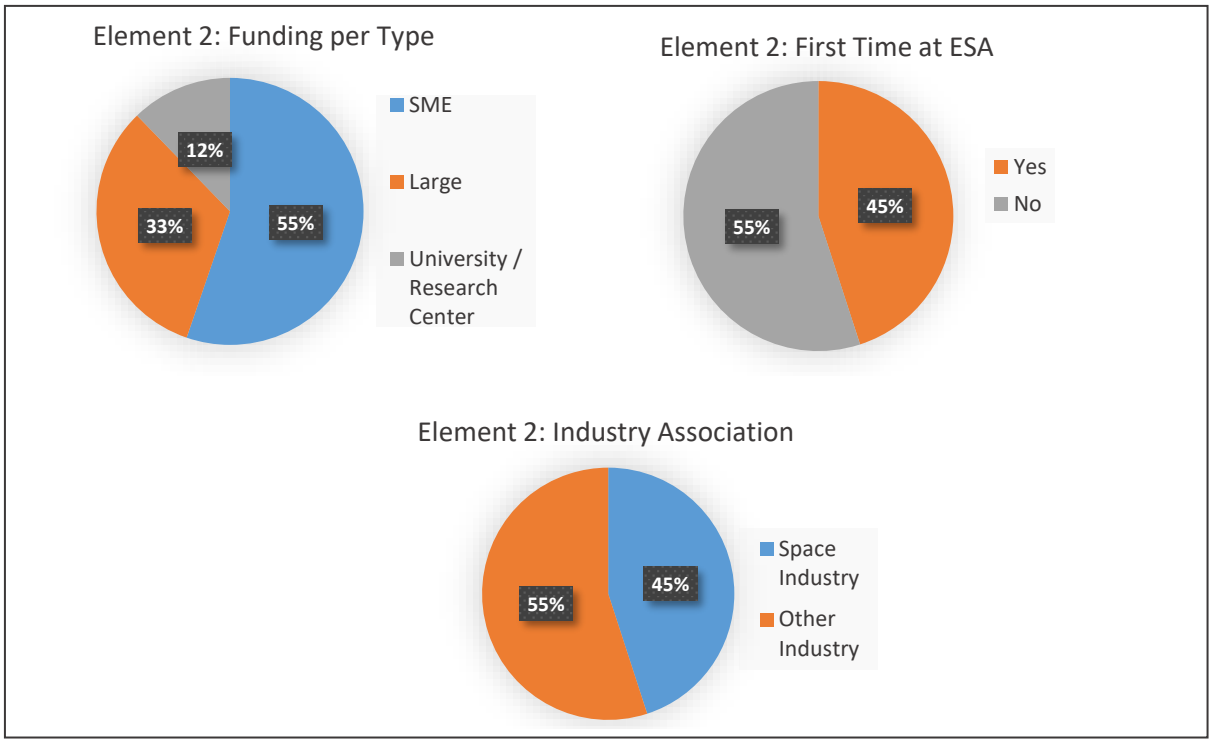


Figure 8: Element 2 Actors Characteristics

The results of the Element 2 evaluation can be found in the subsections below.

3.2.1. Funding by Products

The products and services that the activities encompass are diverse and cover many different technological solutions along the value chain. A large portion of the funding, about 36%, is used to build or develop PNT receivers. Included are, for example, antennas, AI data fusion, machine learning algorithms, and hybrid multisystem receivers. This is followed by the application of PNT services or technologies, next to enhanced systems and services. PNT systems account for 12% of funds, followed by systems for monitoring GNSS performance and detecting interference and spoofing. Test tools and facilities account for 8% of the funds.

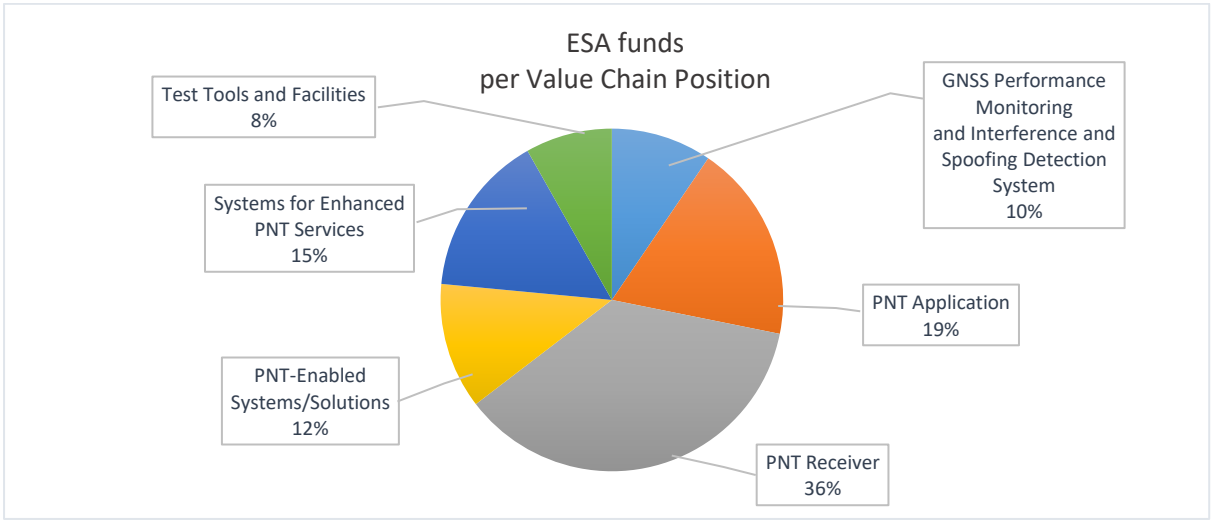


Figure 9: Element 2 Distribution of ESA Funds per Product

3.2.2. Funding by Markets

The products developed under Element 2 are penetrating several market areas, some of which are very new and have not yet been approached by ESA. Around 26% of the funds are dedicated to activities involving different transport sectors, e.g. rail, road, maritime or aviation. This is followed by transversal technologies and services (~19%). Energy and Finance account for around 6% and show in particular the importance of time related services.

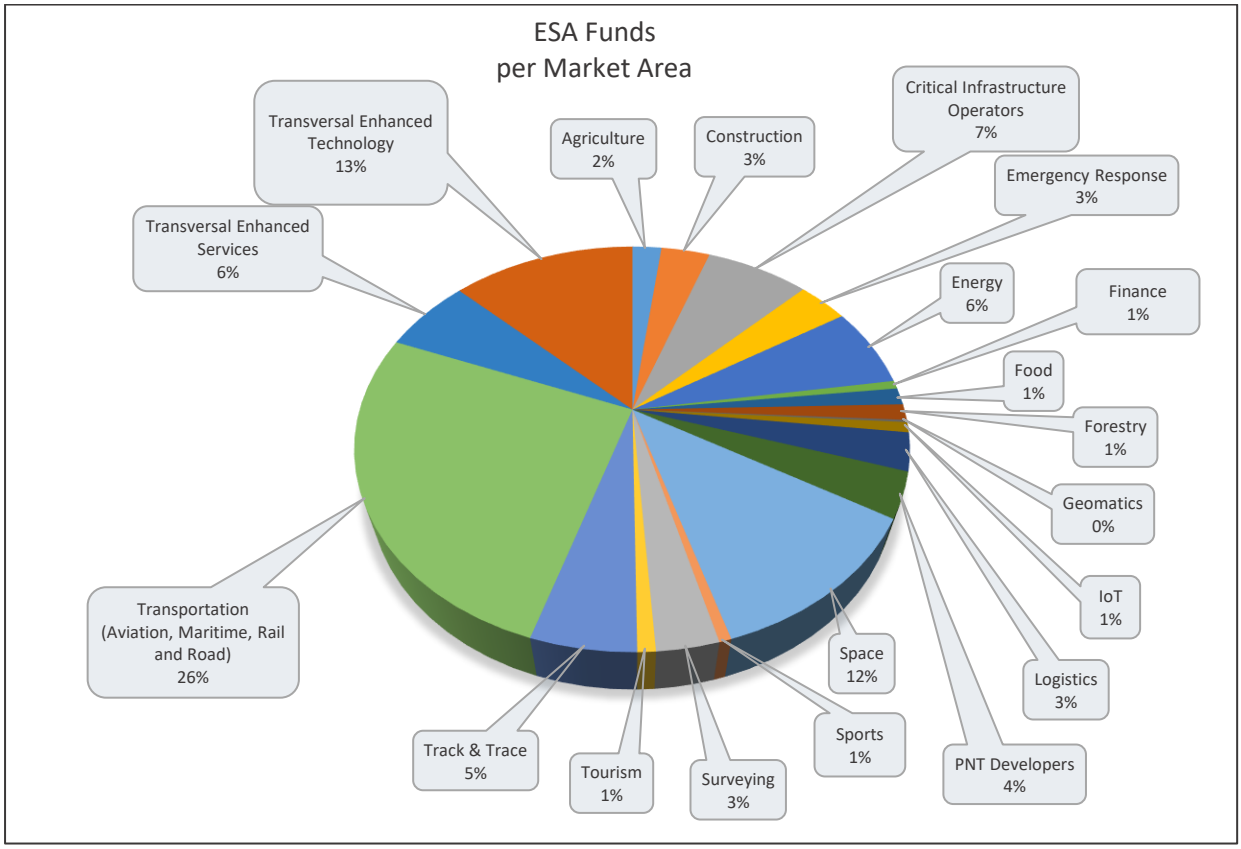


Figure 10: Element 2 Distribution of ESA Funds per Market Area

Compared to the results presented for 2019, it can be observed that the share of allocated funds has rather decreased in the space sector, while it has increased in the transport sector, but also in smaller sectors such as construction, agriculture, food, and sports. This shows that NAVISP has been able to promote the exploitation of new markets and diversify its portfolio of sectors addressed, thus targeting players whose main business is not related to space in line with the NAVAC recommendations[4].

3.2.3. Funding by Challenges/Objectives

To assess which market sector was associated with which challenge, or in other words, which objectives were pursued in each sector, the distribution of funds among the individual benefits per sector was analyzed. The definition of benefit can be found in Annex B.

[4] REC#10 and REC#11 NAVAC 2019 report

The results are presented in Figure 11. Across the sectors, it can be seen that improving performance in terms of accuracy and availability takes up most of the resources, followed by the optimization and the increase of robustness and resilience. For example, the biggest challenge in the agricultural sector is to improve performance. This includes, for example, improving accuracy and ubiquity. The space sector, on the other hand, is mainly confronted with optimization tasks as for example a minimization of costs, size, weight, volume, or power consumption. Projects addressing the largest sector, transportation, are primarily concerned with increasing performance, robustness, and resilience, and generally advancing the general development. As expected, projects related to the use of PNT in critical infrastructures emphasize robustness and resilience.

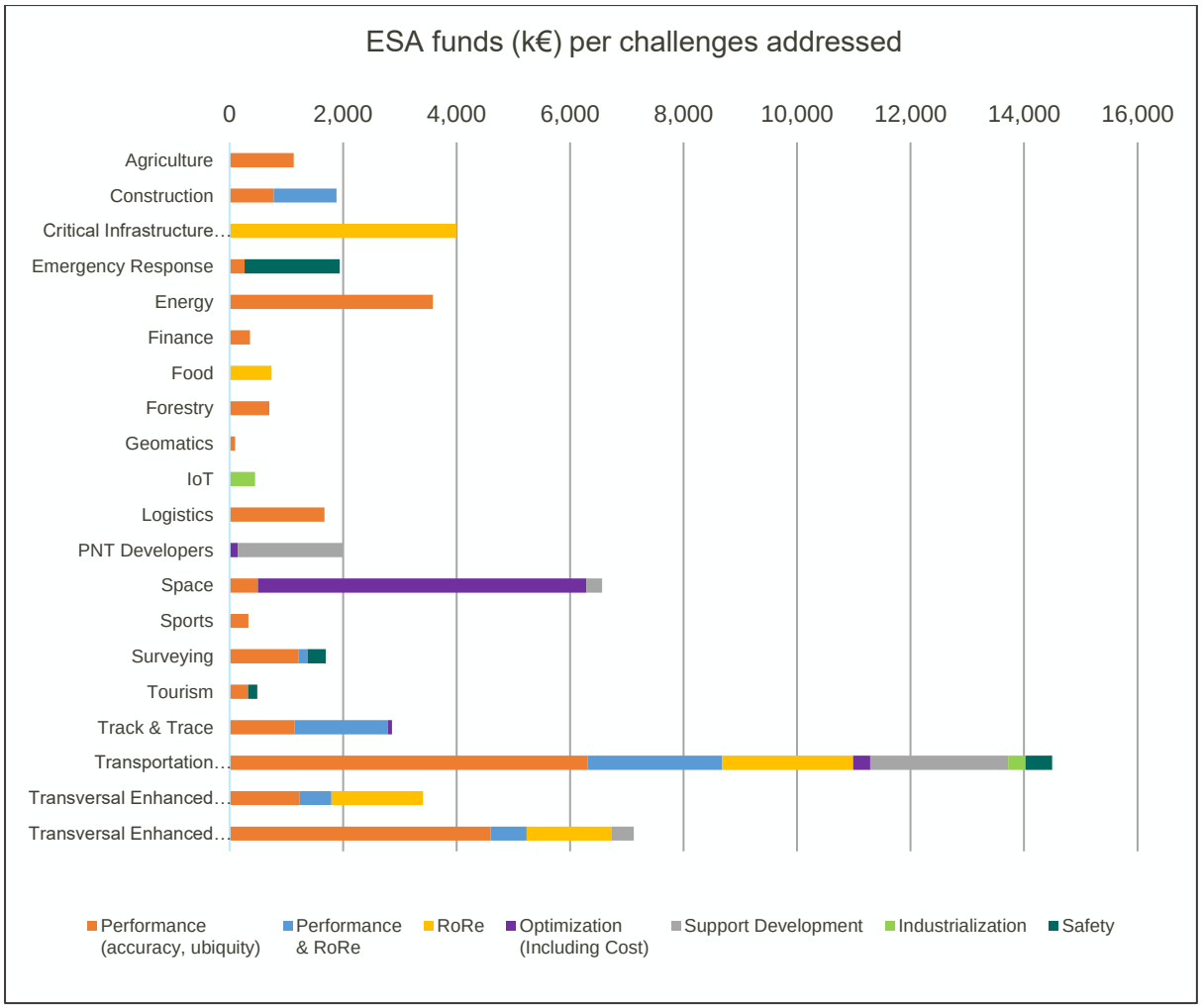


Figure 11: Element 2 Distribution of ESA Funds per Challenges Addressed

3.2.4. Funding by Innovation Category

The majority of the Element 2s budget is allocated to Innovation Categories 2 and 4, which have the highest technological innovation potential. At over 50%, Category 2 clearly holds the largest share of funding in Element 2. This involves all activities that developed new techniques or technologies and address already existing markets (see Figure 12).

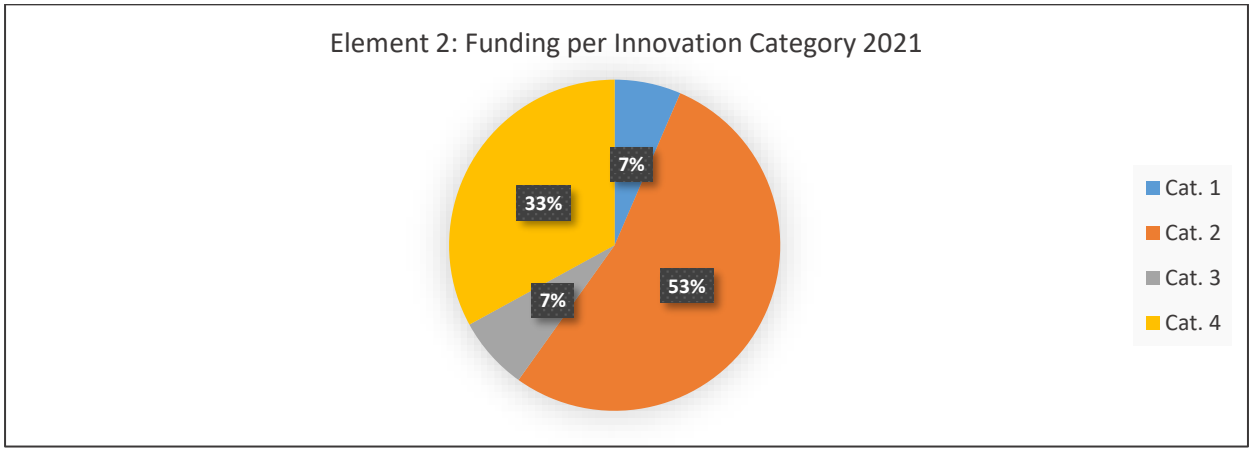


Figure 12: Element 2 Funding per Innovation Category

Since Element 2 has a direct market proximity and seeks to commercialize innovations, Category 2 is of particular importance. Category 3 includes around 7% of the funds, and only 6% of the funds are assigned to Category 1, the introduction of an already existing technology to an existing market.

Compared to the results presented in 2019 (see Figure 13), in particular funding in Category 4 has increased, while funding in Categories 1 and 3 has almost stayed the same and funding of Category 2 has decreased. This shows that the industry's interest in addressing new markets is increasing, indicating the willingness to accept more risks. Element 2 is able to properly prioritize the development of technologies in new and existing markets, while at the same time supporting not only disruptive but also incremental innovations. Thus, Innovation categories 2 and 4 take on a high weight[5], with a focus on new, often disruptive technologies, while categories 1 and 3 involve the adaptation of existing technologies to current needs in the form of incremental innovations[6].

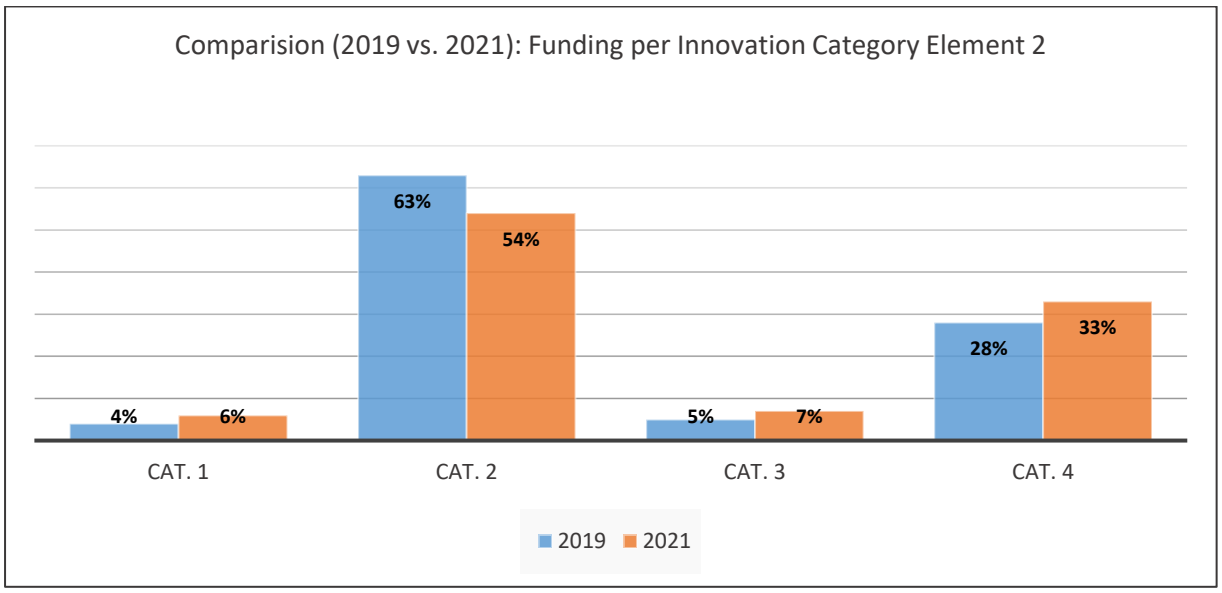


Figure 13: Element 2 Comparison- Funding per Innovation Category

[5] See for example EL2-071 or EL2-53

[6] See for example EL2-055 or EL2-116

3.2.5. Funding by Risk Area

Looking at the distribution of funds by risk area, technological risks can be identified as dominant. About 73% of the funding is aimed at counteracting technological risks. About 23% of the funds are aimed at minimizing market risks, and only 4% are associated with regulatory risks (see Figure 14).

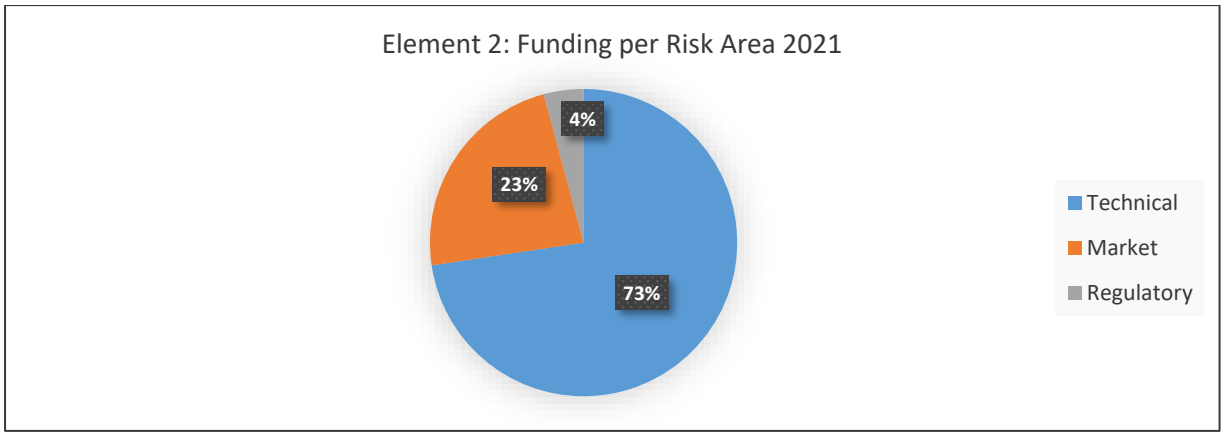


Figure 14: Element 2 Funding per Risk Area

Compared to the results presented in 2019 (see Figure 15), less funding is allocated for activities targeting technical and regulatory risks, while the mitigation of market risked has increased[7]. This highlights Element 2's positive development and ability to help companies bring innovations to market and reduce associated risks. Since Element 2 is aimed in particular at developing new technological innovations and bringing them to the market, the distribution of funds reflects the contextual set-up of Element 2.

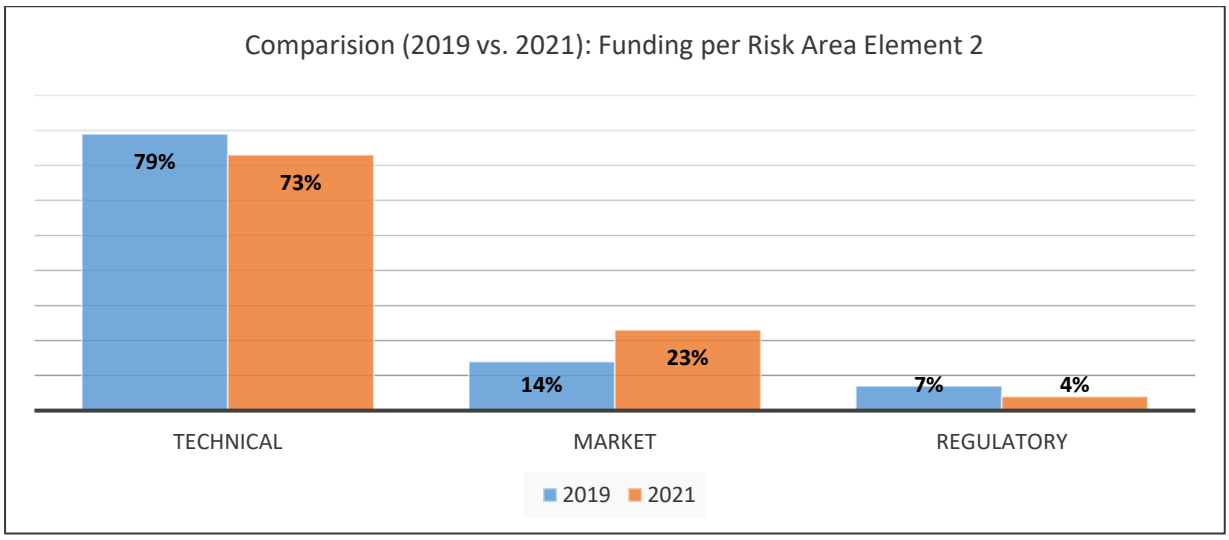


Figure 15: Element 2 Comparison- Funding per Risk Area

3.2.6. Preliminary Conclusion with Respect to 2019 Assessment

Overall, Element 2 has shown a very positive development. The evaluation and comparison with the results presented in 2019 show that the underlying conditions for Element 2 are designed in such a

[7] REC#7 NAVAC 2019 report

way that technical and market risks can be addressed, while at the same time supporting activities that have high innovation potential and, in some cases, even target new markets. In particular, the increase in Innovation Category 4 highlights this assumption and shows that industry is ready to use NAVISP funds to address new markets.

In addition, the share of activities that are aimed to mitigate market risks is expected to grow further in the future with the completion of activities which at the moment are mostly aimed to reduce technical risks/The more activities are successfully completed, the greater the likelihood of commercial products being launched, the greater the need to manage the associated risks.

On the other hand, the industry's interest in using the NAVISP instrument to reduce regulatory risks is still low, and possibly specific outreach actions should be initiated by the ESA Executive to exploit NAVISP in this direction fully.

In addition, it is important to emphasize that the activities under Element 2 have become much more diverse over time, and a wide range of technological solutions have been developed for different markets and customers. The number of sectors in which the solutions can be used has increased significantly and new sectors have been identified. The provision of time-related technologies and services, for example, has increased and it can be seen that these will be in greater demand now and in the future, especially in the energy and finance sectors. Precise timing is essential, for example, in the promising area of smart grids but also for real-time bank transfers. Moreover, in the field of transport, NAVISP has managed to attract a considerable number of activities. These positive developments are considered the result of the efforts of the ESA Executive to increase the outreach of the programme for example by launching Thematic Windows[8] in line with previous NAVAC recommendations[9].

Therefore the focus should continue to be on the development of a broad range of different innovative complementary and alternative PNT technologies that cover everything along the value chain, from the development to the commercialization of products and services.

3.3. Element 3

Element 3 activities were assessed based on funding by objectives, innovation category, and risk mitigation. These categories were used by NAVAC members to evaluate the distribution of funding from 2017 to the present. A total of 18 activities, at different stages of implementation, were considered for the following evaluation, representing a total budget of 15.069 K€. The results of the Element 3 assessment can be found in the sub-sections below.

3.3.1. Funding by Objectives

Based on their objectives, different types of activities can be distinguished:

- Activities addressing the topic of PNT resilience, either within a particular domain (maritime, in-land waterway) or in general by making a national survey of the criticality of

[8] "Assisted GNSS with Imaging Sensors and 3D Models" Thematic Window launched in July 2021 and the "PNT in 5G "Thematic Window launched in October 2020.

[9] REC#9 and REC#10 NAVAC 2019 report

the topic in critical infrastructures, or by developing tools and facilities to detect events impacting PNT resilience (e.g. interference).

- Activities addressing the implementation of test-beds to support the development of PNT solutions in specific domains (maritime, UAV's).
- Other, such as the improvement of the national geodetic reference frame or how the use of PNT can be used in synergy with national regulations.

Due to the increased reliance on GNSS, PNT resilience has become a national priority. This category accounts for almost half of the funding (see Figure 16): around 43 % of the funding was assigned to activities focusing on improving the PNT resilience. However, with approximately 51 %, PNT Test-Beds count for the majority of the funding.

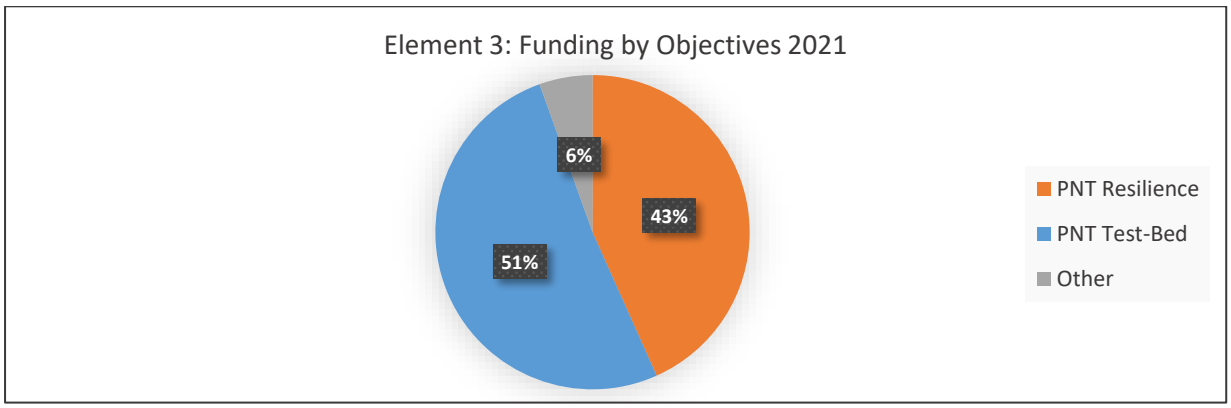


Figure 16: Element 3 Funding by Objective 2021

Compared to the results presented in 2019 (see Figure 17), it can be seen that the general trend changed in the last years giving more weight to the implementation of PNT Test-Beds. The Element 3 instrument is also starting to be used to support other type of activities with the common denominator that those are of general, and transversal nature, like the improvement of a national terrestrial reference frame to benefit from high accuracy positioning services.[10]

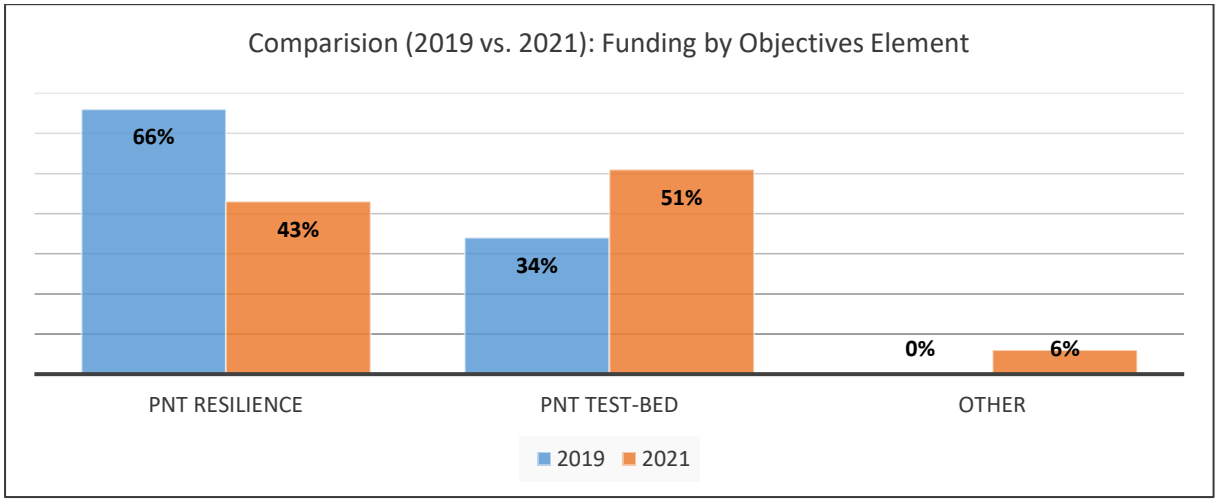


Figure 17: Element 3 Comparison- Funding by Objective

[10] For reference see EL03-008

3.3.2. Funding by Innovation Category

The majority of the Element 3s budget is allocated to Innovation Category 2. With almost 70%, Category 2 clearly holds the largest share of funding in Element 3. This involves all activities that developed new techniques or technologies and address already existing markets (see Figure 18). Element 3 is aimed at national projects addressing existing markets (national customers) in the first instance. Accordingly, Category 2 in particular plays an essential role in this area.

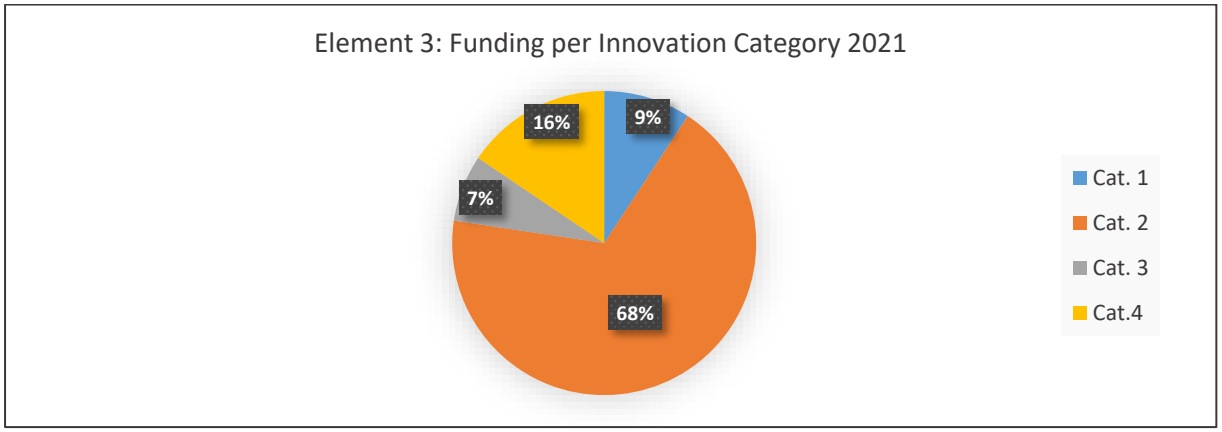


Figure 18: Element 3 Funding per Innovation Category 2021

In comparison with the results from 2019, it can be seen that the distribution of funding has changed significantly. This is mainly due to the fact that in 2019 only a qualitative assessment was possible, as many projects were not yet under contract or had just started. Accordingly, the current results show a more consolidated vision. However, the tendency for Category 2 to dominate has been maintained.

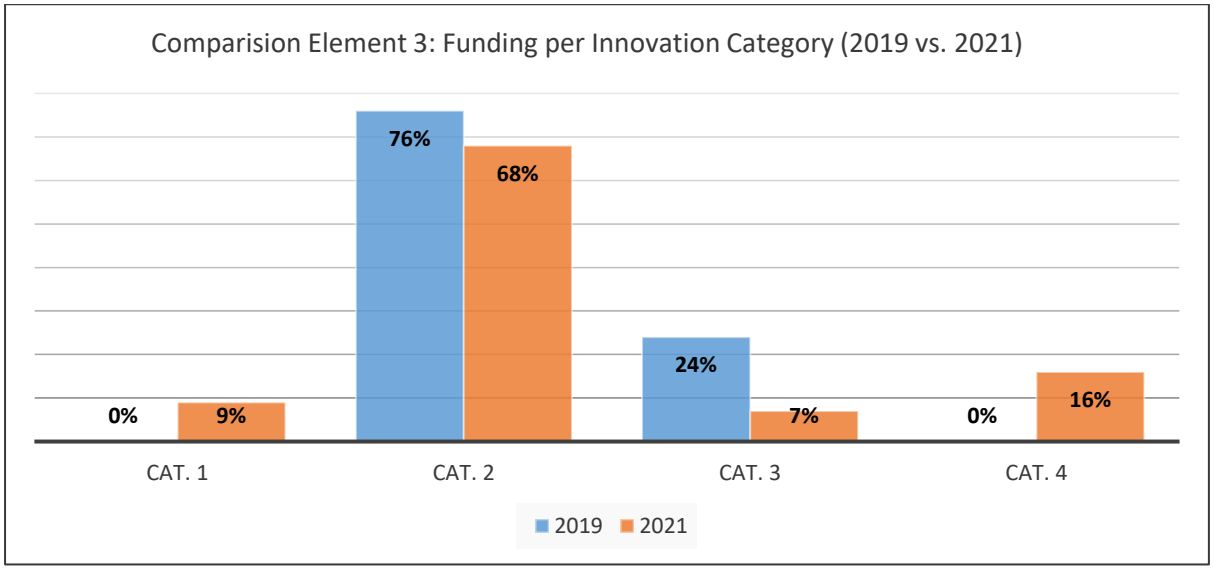


Figure 19: Element 3 Comparison- Funding per Innovation Category

3.3.3. Funding by Risk Area

The distribution of funds by risk area shows that technical and regulatory risks are equally dominant. About 44% of the funding is aimed at counteracting technical risks through this Element of NAVISP. About 42% of the funds are aimed at minimizing regulatory risks and 14% are associated with market

risks (see Figure 20). Since Element 3 is aimed in particular at supporting PNT national programmes and relevant institutional activities following ad hoc participant Member States' requests, counteracting regulatory risks is as important as mitigating technical risks.

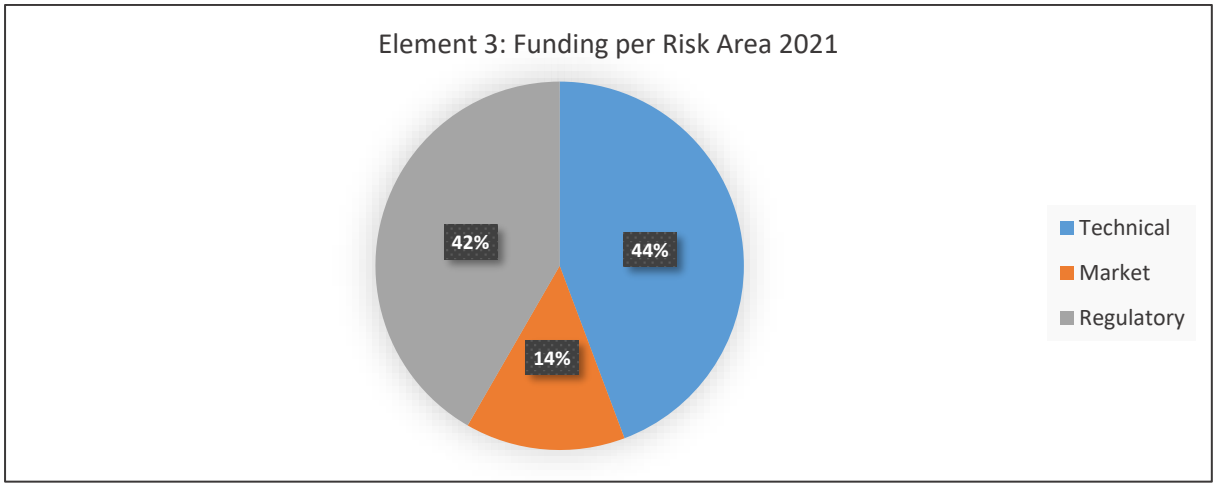


Figure 20: Element 3 Funding per Risk Area 2021

Compared to the results from 2019, it can be seen that the amount of funding in the area of technical risk has remained the same, while regulatory risks have decreased slightly and market risks have increased by this amount. However, there is a certain amount of interpretation on these results as it could be argued that an activity developing a service to detect interference is either addressing the reduction of regulatory risks when considering the risk of interference to safety-of-life applications or reducing a market risk, when considering the impact of interference in the operation of a commercial PNT service. Consensus among NAVAC members on this matter was not always possible.

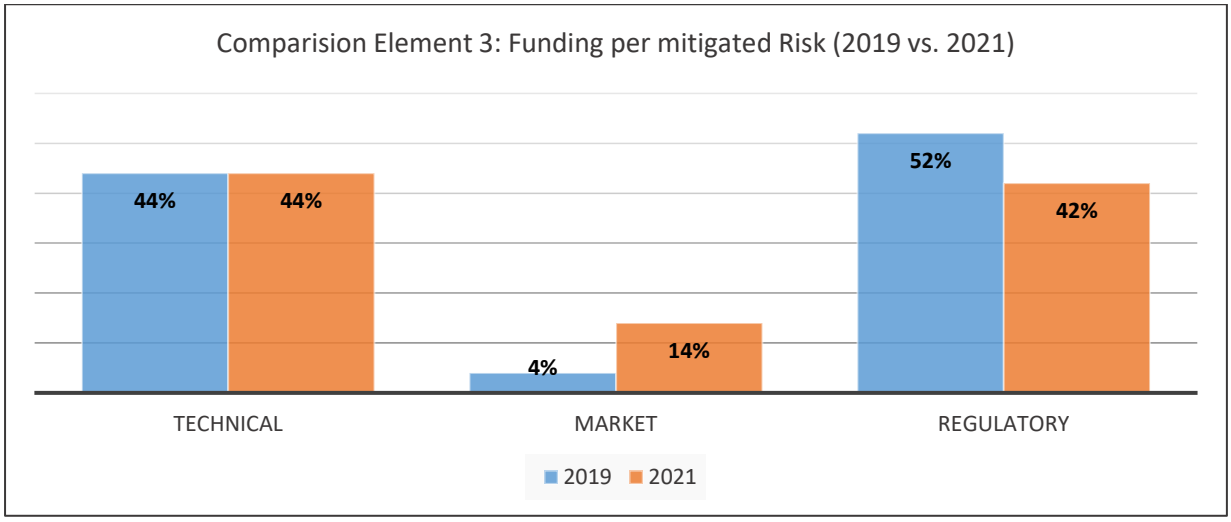


Figure 21: Element 3 Comparison- Funding per Risk Area

3.3.4. Preliminary Conclusion with Respect to 2019 Assessment

While the evaluation in the 2019 report on Element 3 was rather brief and included only a qualitative assessment, the progress of Element 3 can now be clearly seen. Element 3, in particular, addresses national actors and institutions, supporting not only the development of products and services, but more initiative of a transversal benefit to different sectors. While regulatory risks tend to play a

subordinate role in Elements 1 and 2, Element 3 succeeds in specifically addressing them here. In this way, it is possible to increase the awareness and capabilities of complementary and alternative PNT technologies at the European level (see section 2.1 to recall the objectives of Element 3).

4. NAVISP Industry Survey

4.1. Online Industry Survey

4.1.1. Overview Survey

A questionnaire was sent out in August 2021 to gather feedback from companies participating in NAVISP Element 2 (see Annex C). Such a survey already took place in 2019 in order to be able to determine initial developments in the project, however this time, with the increasing number of companies participating in the programme, the expectation was that the results would be more consolidated. The questions in this year's survey were taken from the 2019 questionnaire and adjusted only as needed. This allowed for a detailed comparison and evaluation of the NAVISP programme's development over the past two years.

The survey serves as a tool for the NAVISP team to monitor the progress over the past several years and to adjust, develop, and modify the programme if necessary. The objectives of the questionnaire were manifold and included:

- General evaluation of the cooperation with ESA
- Identification and evaluation of the economic impact of the projects
- Comments/suggestions on the efficiency of the procurement cycle
- Assessment of the role of Element 2 as a tool to increase the competitiveness of industry

The surveys also assist NAVAC members in deriving recommendations for possible actions to improve the effectiveness of Element 2, with the goal of promoting industry competitiveness. The survey targeted all actors, involved in a NAVISP Element 2 activity at the time, i.e., it was sent to the prime contractors of 80 activities. The prime contractors of 50 activities responded to the survey (63%). The majority of participants (60%) were SMEs and around 40% were large companies. For around 30% of the activities, it was the first time to work with ESA.

4.1.2. Results

This section provides an overview and analysis of the survey results. The survey started with the evaluation of the procurement process. Subsequently, the participants were asked how the cooperation with NAVISP has affected the company in size and growth. Furthermore, it is discussed whether the project inspired other companies to enter the PNT market or to enter into collaborations with ESA. This is followed by an analysis of the technical, market, and regulatory risks that the project has faced. The chapter concludes with the general evaluation of the cooperation and the supporting activities carried out by ESA.

4.1.2.1. Procurement Process

Under this point, the companies were asked a number of questions to determine the effectiveness/ efficiency of the procurement process. Results are given in Figure 22. Overall, the NAVISP participants appeared to be very satisfied with the procurement process.

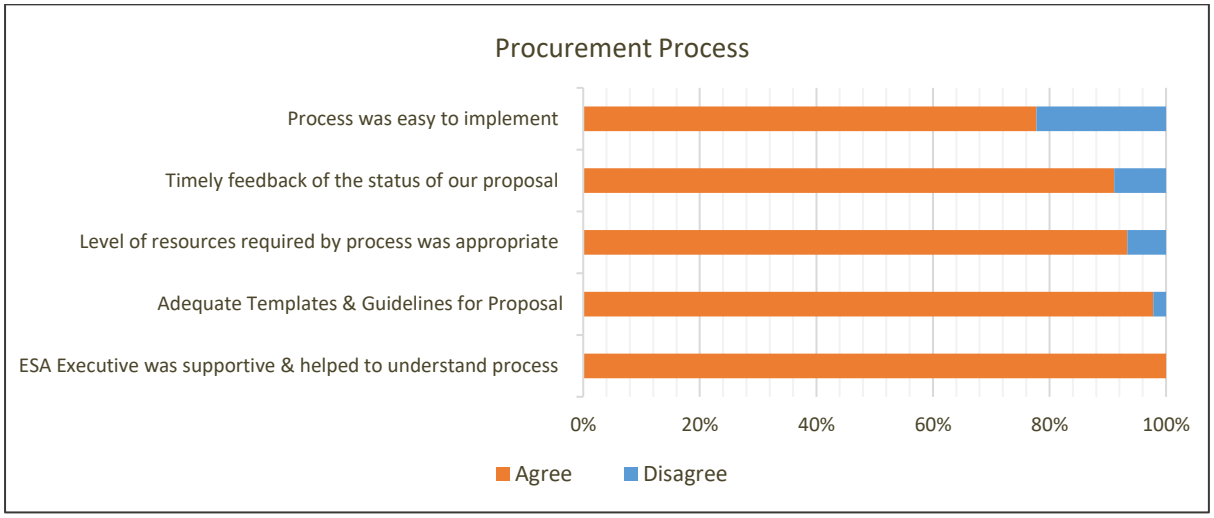


Figure 22: Satisfaction of Participants with the overall Procurement Process

First of all, the professional support provided by the ESA executives was positively received by all participants. The templates and guidelines also seem to be easily accessible and applicable for a large part of the participants (>95%). Furthermore, some participants stated that the guidelines and templates, along with the support of ESA executives, were a great help in successfully completing the procurement process. Likewise, the level of resources required was perceived as appropriate by over 90%. The timing and feedback on the status of the proposal were also perceived as positive and therefore sufficient by a majority of respondents. Only around 9% of respondents disagreed with this statement.

In order to facilitate the procurement process further, some companies pointed out that parts of the proposal could be shortened, that the process between the outline proposal and the final proposal could be improved and that it is difficult to incorporate changes retrospectively. Indeed, in order to facilitate the procurement process, templates and guidelines were designed rather static to give less room for deviations. However, this was sometimes perceived as too inflexible. Therefore, a possible improvement for the future is to make the templates somewhat more open so that they are more of a guideline than a static prescription.

However, in general, 78% of the participants described the overall procurement process as simple and accessible. This feedback is more consolidated than the one in 2019 when the respondents were still very much at the beginning of the process and it was therefore more difficult to obtain an assessment of the procurement process. One participant stated for example:

> *"The process is correct. It takes time and information, but it allows us to think on what we want to achieve."*

4.1.2.2. Contribution to Growth

In the next section of the survey, the companies were asked about how the NAVISP activity has contributed to the company's growth and whether they have hired new employees as a result of the activity. The answers to this question are very encouraging. Overall, 72% of the activities resulted in the hiring of new employees. The majority of companies hired two or more employees. Some activities even led to the recruitment of up to 10 new employees. Three companies additionally stated that they

were able to maintain their employees, which would not have been possible without the NAVISP program, and can therefore also be considered a positive success. Only 20% of the activities did not result in the hiring of new employees. It can be deduced that NAVISP has triggered significant growth from various companies, especially start-ups and SMEs, allowing them to focus on product development. With respect to this, one of the participants stated:

> *"We were able to address a new domain for the company, to create new competences and generate experience. These, in turn, led to further projects that directly benefited from the experience accumulated in our activity. We were encouraged to employ more people with experience in developing mobile applications and marketing"*

4.1.2.3. Risk Mitigation

One of the main objectives of Element 2 of the NAVISP Programme is to reduce the risk for the companies in the introduction of PNT products or services. Thus companies were asked to indicate which risk was mitigated by NAVISP activity. Respondents were asked to identify the: technical, market, business, or regulatory. For this purpose, respondents ranked the different types of risks by their relevance. 65% of respondents indicated that the NAVISP collaboration primarily reduced technical risk. For 23%, on the other hand, mitigating market risks was the top priority. In addition, after technical risks, mitigating market risks is the second priority for more than 60% of respondents. This is an increase compared to 2019, where the share of market risks was slightly lower, especially in the second rank. Regulatory risks therefore play a rather subordinate role. In each case, 12% of the respondents believe that the mitigation of regulatory risks is of first or second priority. Thus, over 60% rank regulatory risks the lowest. However, compared to 2019, regulatory risk (on the first rank) has increased by 12%, demonstrating NAVISP's ability to mitigate regulatory barriers as well. The results are presented in Figure 23.

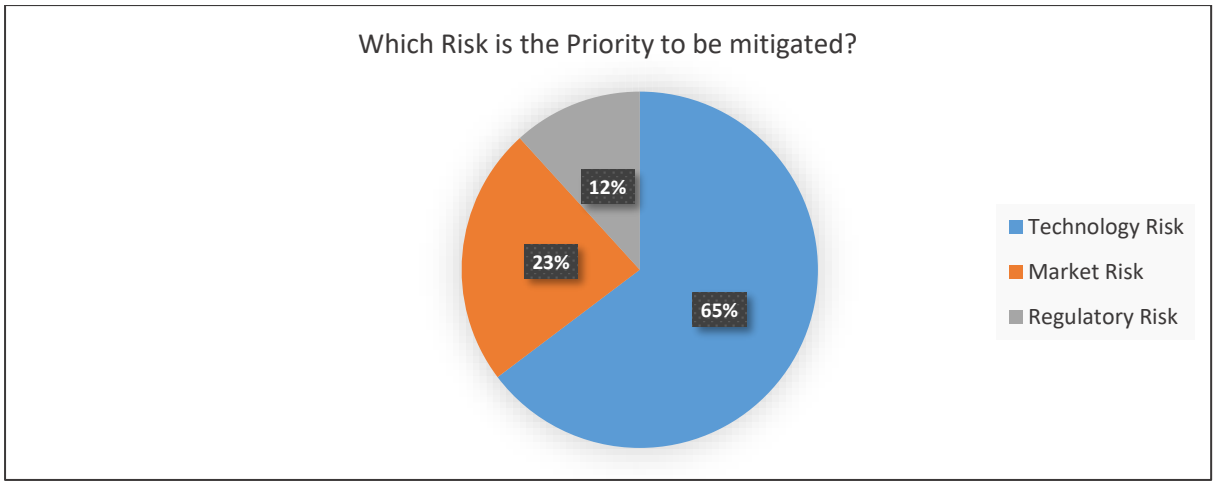


Figure 23: Mitigated Risks ranked on the First Place

NAVISP is considered by a majority of the respondents to the survey as an instrument to reduce the technical risks in the development of their PNT product, followed by market risks and to a less degree regulatory risks. This is in accordance with NAVAC own views (see Figure 14). However, industry's

perception is that a higher level of funding is devoted to the reduction of regulatory risks. Therefore the NAVAC view on this respect should possibly be reviewed.

The importance given by industry to reduce technical risks via NAVISP can be seen in the following two testimonials:

"The activity required us to build and maintain a very specific skill set - this skill set is crucial to the continued development of the technology"

"In our view, the main risk is technological, vs. commercial and regulatory. The development involves relevant technical challenges; it could be (hopefully) used as soon as it is achieved."

4.1.2.4. Overall Assessment of cooperation and different ESA supporting tasks

In the final part of the survey, companies were asked to share their experiences of applying for and conducting an activity through NAVISP, including an assessment of the benefits of ESA's various supporting roles: from technical expertise support to the value of the ESA brand to their product. For this purpose, the general cooperation was investigated first. The results are presented in Figure 24.

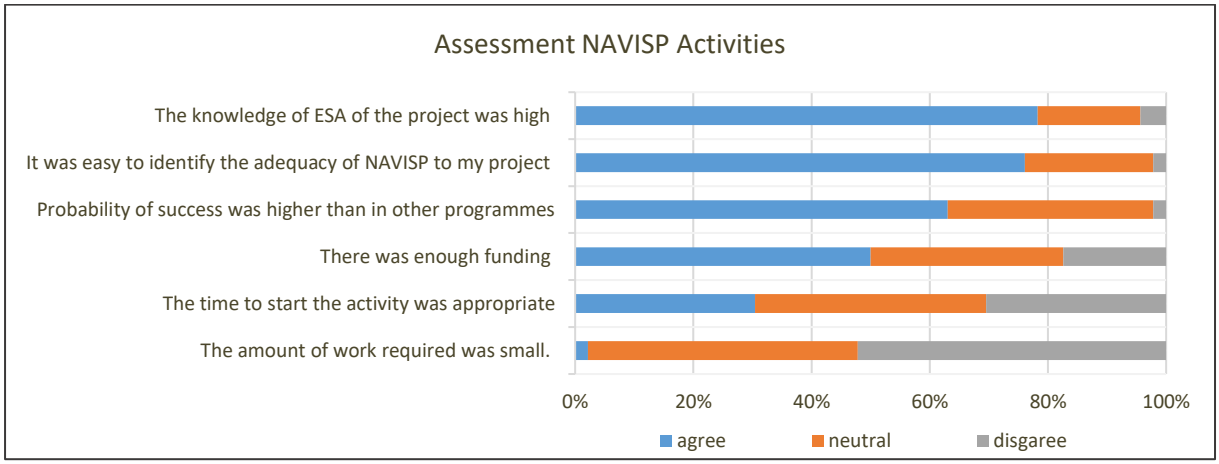


Figure 24: General Evaluation of NAVISP Collaboration

The time to approval, the amount of work and the level of funding were identified by participants as the most significant barriers. Those two areas, in particular, represent common obstacles projects face when seeking funding. In 2019, 39% of respondents stated that the time to start activities was too long. Today, on the other hand, it is only 30%. This shows that NAVISP has improved significantly in this area. Nevertheless, there is room for further optimization.

What remains unchanged compared to 2019 is that around half of the respondents consider the workload to be high. The workload is related on the one hand to the preparation of the proposal and the administrative part of the contract preparation. In addition, there is the actual project implementation, including possible difficulties and delays in the process. These may arise due to organizational, technical, or personnel challenges and are difficult to foresee. Projects that involve the development of a technology, in particular, are therefore always associated with much work. However, within the possibilities of NAVISP, the organizational steps from the application to the

approval as well as organizational steps in the duration of the project are to be designed as efficient and lean as possible. Therefore, the NAVISP team should continue to focus on a constant monitoring of the individual steps, from the preparation of the contract to the implementation and dissemination of results in order to optimize them and avoid the unnecessary workload from the industry.

Last, the level of public funding is a point of criticism for many companies. About 17% of participants believe that public funding is insufficient, and another 30% believe that the level of public funding limits the feasibility of projects. A study of the European Investment Bank (2019) on the other hand found that only about 6%[11] of the companies were dissatisfied with the level of public funding (e.g. through the Horizon2020 programme). Thus, the percentage from companies participating in NAVISP, is still below the general satisfaction of companies in other European financing programmes. As stated in the EIB report, public funding is particularly important, not only because it is often a prerequisite for private investments, but also because it serves as a seal of approval in the markets. In addition, the intention of NAVSIP is to support activities with high innovation potential and thus also high possible market and technical risks. Therefore, it is essential to provide sufficient resources to motivate and support companies to take risks and enter immature markets with uncertain demand, often high technical risks, and high capital requirements. Thus, to ensure the long-term success of activities within NAVISP, it is crucial to provide and, if possible, increase public funding.

With regard to the other questions, the participation in NAVISP is considered clearly a success. In fact, more than 60% of the participants state that the NAVISP program increases the probability of success compared to other funding programs. Likewise, the technical expertise as well as the support of the NAVISP team and the entire ESA was appreciated by around 80% of the participants.

This leads us to the more specific questions regarding ESA's supporting functions, including technical expertise, brand, and networking capabilities. The results can be found in Figure 25.

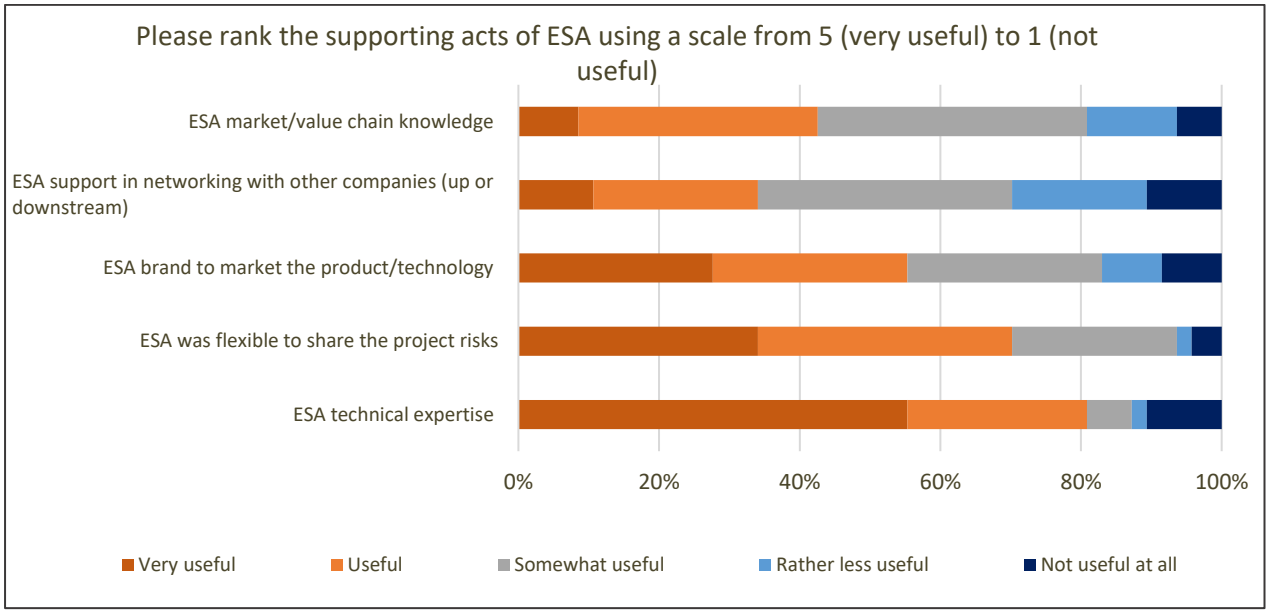


Figure 25: Evaluation Supporting Acts of ESA

[11] EIB Financial Report p. 101

The answers show, as already indicated, the strong appreciation for ESA technical expertise. Over 80% of the participants found the technical knowledge offered by ESA useful or even very useful. One Company stated:

"Our ESA TO was very supportive, offered his huge technical expertise, was open for discussions and thus helped us to come up with a viable product. In our opinion this activity was a true success"

In a similar way, the participants appreciated the flexibility of ESA to share project risks. Only 7% of participants considered ESA's risk-sharing flexibility to be unhelpful. The following statement shows a participant's appreciation for ESA's flexibility and support:

"NAVISP team have been hugely supportive to our goals and ambitions. Without their help, we would not have come this far at this point in time."

Although more than 30% of respondents find the network capabilities beneficial, 36% of respondents think they are only partially useful, and approximately 28% see this capability as not useful. Therefore, this is an area for improvement in the programme.

Similarly, ESA's market knowledge is valued, but at a lower level than other aspects of support. Approximately 20% did not find this supporting activity useful. It is however not apparent in this question why this is the case. Companies that are still in the early stages of their operations and thus do not yet need access to such competencies may have answered this question accordingly. Therefore, it will be a task for the NAVISP team to address more of the possible criticism in the coming period.

In summary, however, it can be said that the majority of the respondents were more than satisfied with the collaboration. Through NAVISP it was possible to open up new application areas for PNT or to expand already known application fields and thus to increase the European competitiveness. In the coming months, more projects will be contracted and others will be completed. Thus, the progress of the NAVISP program is of interest for both, ESA and the European industry.

"We believe that the NAVISP-Element 2 programme should be further extended to other disciplines other than PNT. And to favor a technical liaison between rail and satellite experts. Rail ecosystem is evolving and PNT and Satellite technologies are key to improve industrial competitively and provide tangible benefits to train operators and passengers."

4.2. Interviews for Completed Activities

4.2.1. Overview Interviews

To obtain a more detailed overview, in addition to the online survey, interviews were conducted with companies that participated and completed an activity within Element 2. The goal of the interviews was to gather feedback on how NAVISP has benefited the companies and their projects. A total of 17 invitations were sent out, of which 14 interviews were conducted by the end of 2021. Of the 14 interviewed companies, 9 were SMEs and 5 were large companies. The objectives of the interviews were manifold and included the assessment of the following topics (Table 3):

Topic	Indicators
Market Increase	○ Increased market share of existing market

	○ Access to new markets (new geographical markets for markets where the company was already accessing, Access to new sectorial markets, any competitive lead in a specific market acquired?)
Technological; advantages acquired	○ Technical innovation/ Most competitive product characteristics: (quality/performance, costs, increased product portfolio, enhancement of the staff's skills and knowledge, TRL increase enabled by the project, technology transfer for or from the project execution (spin-in/spin-off) , IP/patents)
Managerial Enhancements	○ Increased efficiency through improvement of internal processes and operations ○ New management skills acquired according to Management requirements of the Call (including risk , register, test plan, validation plan, Gant, Business models methodology)
Company's development	○ Additional Sales ○ Proportion in home country/ in EU/ WW ○ New customers acquired (number/nature/names), ○ Gross Value Added, New facilities/assets developed ○ New partnerships established (in home country, in EU, WW), ○ Jobs created or maintained by the project / Jobs created or maintained by additional sales (in home country, in EU, WW
Future of the Project	○ After conclusion of the activity with ESA, were additional funds/activities needed to put the product on to the market? Value of these additional investments? Were these funds from external sources (external public/private) or own investments? ○ Would a further support by ESA needed/helpful? What kind? ○ What is the time after the conclusion of the project with ESA to have the product on to the market?
Benefit working with ESA	○ What is the most important benefit from working for ESA? ○ Would you benefit from partnering with other international entities to improve the effectiveness of the development? ○ Would you benefit form a support by ESA to protect the IPR developed during the activity (e.g. definition of the strategy for the protection of the intellectual property and its commercialization, patent application, etc.?)

Table 3: Topics and Indicators addressed in Interviews

4.2.2. Results of the conducted Interviews

The following sections provides the results of the conducted interviews and includes a more detailed feedback about how NAVISP has benefitted companies and their projects by assessing the Technological Readiness Level, commercialization potential and competitive characteristics as well as the assessment of whether NAVISP activities have contributed to growth, including potential managerial enhancements.

4.2.2.1. Market Increase & Market Advantages required

One of NAVISP's goals is to bring technological innovations to the market. Overall, four of the 14 activities that participated in the interviews achieved commercialization at the end of the activity. Those that achieved commercialization indicated that their market share increased in their existing market. In addition, the commercialized activities gained access to new geographic and sectoral markets. Moreover, some of the commercialized products were shown to have sort of competitive advantages in the specific market acquired. It was also found that some of the commercialized products and services have the potential to disrupt other technologies that were previously used to serve these markets. In general, the completed projects demonstrated improved in their competitive characteristics of their products compared to others, such as performance, costs or breakthrough innovations. In general, the completed projects have demonstrated that their products are competitive with others, e.g., in terms of cost or in particular performance. Some of the newly developed products have been shown to complement other existing products in the companies' portfolios, while smaller companies in particular have been able to develop entirely new products

based on their existing expertise. The development of new or complementary products has thus significantly expanded the skills and knowledge of employees.

4.2.2.2. Managerial Enhancements and Companies development

Overall, the activities contributed to the growth of the companies for example in acquiring new customers but particularly in improving managerial skills. This was more evident in smaller companies, which indicated that they had acquired new management skills as a result of the project. The companies stated, that the business methodology was generally enhanced within the activity, by constantly monitoring and if necessary, updating the business model. Thus, the companies experienced increased efficiency through the improvement of internal processes and operations. One company stated:

"NAVISP has guided the approach to development and has put in place an effective structure to follow leading to increased robustness"

Commercialized activities acquired new customers and companies that are near commercialization specified potential customers that are interested in the product. Moreover, partnerships had been established for the majority of companies which have yet to reach commercialization. For companies that reached commercialization their partners ranged from in home country to EU and worldwide. In addition, 11 out of the 14 companies reported jobs were created as a result of the completed activity. Those that did not hire new employees reported that jobs were maintained.

4.2.2.3. Future of the project and Benefits of working with ESA

Since not all activities were able to bring the product to market at the end of the NAVISP activity, additional funds were needed, in order to successfully finalize the development. In all cases, the funds used for commercialization after the activities were completed came from in-house investments. No funds were raised from external sources to bring the product to market. Around the half of the companies stated that further support by ESA would be helpful in order to commercialize the product. The time that it took for the products to reach the market after the activity was completed ranged from a few months to three years.

Overall, the companies expressed their satisfaction of working with ESA. In most cases the ESA logo proved to be helpful in raising awareness, giving credibility and raising additional funding to the products the companies were launching. In general, the cooperation with ESA was perceived as very helpful, in particular due to the technical expertise and assistance during the projects. One company stated:

"Having real experts to discuss ideas and technical problems with Expert review at different phases (requirements, design, development, test readiness and validation) is so helpful. Our was super supportive. We had great discussions and he tried to assist the product development. - Support from ESA beyond the project runtime (marketing, using ESA logo, …)."

The companies also stated the desire to benefit from partnering with other international entities to improve the effectiveness of their development. These benefits include access to new markets, promote the product and support in growth. In addition, all companies were interested in receiving further support by ESA to protect the IPR developed during the activity.

4.3. Preliminary Conclusions with respect to 2019 Survey

The results of the industry surveys, including the online survey and the interviews, indicate that the majority of NAVISP Element 2 participants were satisfied with the collaboration and its output. ESA was able to support the development of technologies up to their commercialization, especially with the technical expertise, the flexibility in risk-sharing as well as with the marketing and the use of the ESA brand. Due to the participation in NAVISP, companies were able to further expand their knowledge, for example by hiring new employees. While in 2019 many of the respondents could only make assumptions, as most of the projects were still in the early stages, the expectations set at that time were exceeded.

Although the COVID-19 pandemic has made it difficult to track the exact successes and has further complicated development and commercialization processes, the NAVISP program has helped to support many companies and raise their profile. Many participants report that by participating in the NAVISP program, technologies could be developed from an early proof of concept to something that can be more solidly tested and demonstrated or even commercialized.

However, the Industry Survey also identified some issues that should to be addressed in the next phase to further improve the quality of the programme. The following points should not be taken as negative, but rather show that the surveys and interviews have achieved their goal. Continuous monitoring makes it possible to detect current weaknesses and thus refine and develop the program in detail and thus adapt it to the current needs of the participants.

First, although most participants were satisfied with the overall procurement process, some requested further simplification. Among other things, a leaner design of the process was suggested. Accordingly, they recommended that ESA should review the procurement process and enter into a more in-depth exchange with the companies in order to clearly identify and resolve possible shortcomings. Second, the market knowledge of ESA was appreciated, but at a lower level than other aspects of support (20% did not find this supporting activity useful). Reasons for this however can be manifold. Companies that are still in the early stages of their operations and thus do not yet need access to such competencies may have answered this question accordingly. However, it should be a task for the NAVISP team to address this kind of criticism including its origins in the coming period.

In addition 36% of respondents think the networking capabilities of NAVISP are only partially useful and approximately 28% see this capability as not useful. Therefore, this is an area to be reinforced taking advantage of the growing database of contacts being collected by the programme through the various outreach activities.

The question of the level of funding was also raised by the participants. Stable funding is therefore important in the future to ensure the continuity of the program, expand its outreach, attract new companies and increase the chances of success.

5. NAVISP Success Stories

While the above sections offered initial insights into the distribution of resources and the contextual structure of each element, this chapter provides an exemplary overview of success stories per element to further identify the added value and addressed sectors of NAVISP. To this end, a conclusion is provided to summarize and highlight key actions of NAVISP in the last years.

5.1. Success Stories Element 1

Element 1 has promoted activities with a high level of innovation, focusing on the mitigation of technical risks and developing and maturing new PNT technologies. The following sub-section presents some exemplary activities that demonstrate the high innovation potential and successful outcomes of NAVISP collaborations under Element 1.

5.1.1. EL1-001: Complementary PNT Infrastructure in LEO

As part of NAVISP Element 1, Surrey Satellite Technology LTD and Airbus Defence and Space LTD led two parallel studies on LEO-based PNT systems that can add valuable capabilities to a GNSS backbone such as Galileo and/or multi-GNSS, particularly but not exclusively in terms of improved resiliency, improved coverage of emerging needs and use cases, and improved penetration in challenging environments.

At that time, in 2018, the topic of LEO PNT was only being study in academia while today, LEO constellations are a very popular topic. Companies like Starlink, Kuipers, OneWeb, Xona Space, and Iridium see LEO as the future for navigation and communication from space.

These two studies are an example of how thanks to the expertise of the ESA experts participating in the preparation of the NAVISP Element 1 workplans, it was possible to anticipate this important trend and identify new PNT technological opportunities.

5.1.2. EL1-006: PULSAR Timescale

Under Element 1, the consortia formed by GMV Innovating Solutions, the University of Manchester, and the National Physical Laboratory, examined a complementary timescale generation method independent from atomic clocks. The focus relied on a pulsar timescale demonstration, a time scale built with pulsar measurements, i.e. measurements from celestial objects emitting radiation in pulses. In the short term, this would generally be less stable than one built with atomic or optical clocks, but could be competitive in the long term. An additional advantage is that it would be independent of the clock technology for generating the oscillation mechanisms.

At the end of the activity, a new data collection of pulsar measurements was enabled, which could promote the use of pulsar measurements in the future. In addition, the new pulsar measurements appear to be of much better quality than data from previous efforts. The activity also created the first fully autonomous real-time time scale based on pulsar measurements that ran automatically for over 10 months, allowing for long periods of experimentation.

5.1.3. EL1-011: Resilient, trustworthy, ubiquitous time transfer

As part of NAVISP Element 1, GMV GmbH developed innovative and complementary methods of time transfer, focusing on the use of non-GNSS technologies to address common vulnerabilities of all GNSS-based time transfer techniques, such as susceptibility to spoofing, jamming, and signal blockage (indoors).

To this end, GMV GmbH has developed a prototype, called UTIME, which combines GNSS timing from a sparse network of low-cost, multi-frequency GNSS stations and time distribution over general terrestrial networks. The time distribution is based on alternative techniques such as NTP+NTS (Network Time Protocol and Security) and DTM (Dynamic Synchronous Transfer Mode) that can work over commercially available networks. The solution was tested in various scenarios to ensure the functions and verify the subsequent possible use in various sectors such as Industry 4.0, power grids, or financial markets, including the following categories: open sky, obstructed open sky, light, and deep indoor. Overall, the prototype was able to achieve sub-microsecond accurate time distribution over several hundred kilometers.

Due to the high potential commercial interest, the company is considering a continuation of this activity under Element 2.

5.1.4. EL1-013: Quantum-based sensing for PNT

The UK Company Teledyne e2 explored the potential of the application of quantum effects to PNT. The exploitation of quantum physics has already enabled revolutionary technical applications and industries of enormous economic scale. The market for semiconductors alone is currently worth over 500 billion euros, from which even larger industries are emerging, such as smartphones, computers, software, and so on.

The goal of the activity was the development of a system concept for combined space-based and quantum sensor navigation, the identification of critical technology development for the overall system performance and the demonstration of the initial feasibility of concepts in the field by means of existing prototypes. This included the investigation of the feasibility of using quantum Cold Atom Interferometry (CAI) gravity gradiometers with gravity gradient maps to reduce Inertial Navigation Systems drift over time. In particular, the gravity gradient map matching has proven to be feasible and offers significant improvements in passive navigation. However, the study also revealed, that the level of improvement offered depends heavily on the use case, vehicle dynamics, trajectory, and CAI parameters. Based on the results obtained, there is confidence that improvements could also be achieved for the other use cases, in particular for maritime cases, if sufficiently high resolution gravity gradient maps are utilized. Thus, NAVISP was able to support the knowledge development in a very new and innovative field of alternative & complementary PNT sources.

5.1.5. EL1-020: AI/ML Sensor Fusion for autonomous Vessel

Maritime transport is currently facing new challenges such as significant increases in transport volumes, more stringent environmental requirements, and a shortage of seafarers in the future. One of the many new concepts having the potential to overcome these challenges is autonomous ship navigation. In particular, concepts that allow for more efficient and competitive ship operations while reducing the vessels' environmental impact. In cooperation with the National Land Survey of Finland

and the Aalto University, this activity investigated the application of artificial intelligence and machine learning techniques for the combined use of multiple sensors in maritime PNT receivers for autonomous vessel navigation.

Identified opportunities relied in particular on the integration of GNSS with different environmental sensors as for example visual cameras, microphones, LiDAR, RADAR and Automatic Identification System to provide situational awareness to the vessel. Discussions are underway to extend and continue support in Element 2.

5.1.6. EL1-030: AMELIE

Teleorbit GmbH, together with Frauenhofer IIS developed and tested a new type of antenna with higher gain and wider band to enable more precise and more available PNT applications even in harsh environments. The project is called AMELIE, short for Advanced Multi-Frequency Low-cost high –gain GNSS Antennas for next generation mass-market devices.

Due to the low cost of the resulting design, the high gain and multi frequency feature, the product has promising market opportunities for high-performance mass-market devices as for example smartphones, drones, automotive, and more general the IOT segment. The industry consortia is at the moment involved in the development of a commercial product.

This activity resulted in a patent application.

5.1.7. Element 1 Activities in support to Earth-Moon PNT Programmatic Initiative

The interest of having in the near future an available PNT service for the Earth-Moon system is of growing interest with both institutional and commercial initiatives. One activity, in cooperation with GMV Innovating Solutions Ltd, Saphyron SAGL, and GMV Innovating Solution S.R.L., aims to perform a dedicated system study on the use of multi-constellation GNSS for Earth-Moon missions. This study complements previous studies, confirming feasibility, assessing achievable performance, and identifying a preliminary architecture with possible enhancements to existing GNSS constellations.

Based on these results, another activity to develop a space-based GNSS receiver for in-orbit demonstration was carried out to exploit synergies and develop a prototype space-based GNSS receiver to mitigate the technical risk for future demonstration missions (e.g. the CubeSat LUCE mission proposal). Thus, data can be gathered and further system activities supported. This shows the early efforts of NAV in the moonlight initiative. These collaborative efforts led also to the development of a receiver that will fly on Lunar Pathfinder in 2024. In addition, examples of cross-fertilization were identified and the development of a prototype Space GNSS receiver for future applications was initiated as an activity in Element 2.

5.2. Success Stories Element 2

Element 2’s goal is to maintain and improve the capability and competitiveness of the industry of the participating States in the global market for Satellite Navigation, and more broadly PNT technologies and services. In this context, Element 2 aims to ensure the readiness of the industry to effectively respond to emerging market opportunities by focusing its activities on products ready for the

commercial or institutional markets. The following sub-sections offer some exemplary activities that demonstrate the successful outcomes of NAVISP collaboration under Element 2.

5.2.1. EL2-002: G-Passion

Under NAVISP Element 2, the Italian company Intecs Solutions S.p.A. initiated the G-PASSION (Galileo Public Authenticated Server-based Snapshot positioning) project, which includes the development of an innovative and competitive system in the Satellite Navigation and in the wider Positioning Navigation and Timing (PNT) domain. The object of this project was the design and development of a system for a GNSS server-based position authentication service using the Galileo signal. G-Passion represents a new solution that meets the increasing needs of no-institutional professional actors and civil users, offering GNSS server-based position authentication service using the full spectrum of the Galileo signal. It provides benefits towards vulnerabilities such as interference, malicious jamming, meaconing, intrusion or spoofing. The collaboration with NAVISP enabled the development of a prototype LA terminal with less weight, size, and consumption compared to other terminals. In addition, an authentication server based on cloud technology was realized and the first reference station was installed at the company headquarters.

The company provided the following testimonial:

"Our product enriches our offer in the railway domain and in general our offer in transports (i.e. Avionics, Automotive, Precision Farming machines) and Time and Sync."

"Our product is competitive due to it is innovative concept, performer and its cost/benefit effectiveness."

5.2.2. EL2-007: Space Keys

As part of Element 2, Flightkeys GmbH, together with Integricom, aims to develop a RAIM prediction system offering a modern Application Programming Interface (API), and easy integration into any flight planning system as well as introducing new innovative features that allow an aircraft operator to avoid areas of low GNSS accuracy already during the trajectory creation process. The activity, named Space Keys, offers the latest evolution of RAIM and A-RAIM Prediction Systems and thus presents the ultimate evolution of GNSS RAIM prediction solution for aviation.

Within NAVISP, the project went through two phases: first, the development, implementation, and validation/verification of RAIM, followed by the experimental test phase of A-RAIM - Galileo and A-RAIM. This has resulted in worldwide success, and active commercial customers include airlines in Europe, the U.S., and Asia. In addition, two major global flight planning companies have started direct API integration alongside integration with two flight tracking systems. In addition, SPACEKEYS sits in the U.S. Congressional ADS-B/RAIM review committee, demonstrating the project's significant international commercial impact.

5.2.3. EL2-008: GIDAS (GNSS Interference Detection & Analysis System)

OHB Digital Solutions, in cooperation with the Institute Electronic Engineering (IEE) at the University of Applied Science FH Joanneum Graz developed a GNSS Interference Detection and Analysis System (GIDAS) that enables a continuous 24/7 monitoring of the GNSS frequency bands within a defined

region to automatically detect, classify and localize intentional interference by means of jamming and spoofing. The GIDAS system architecture consists of one or more monitoring stations, including antenna and monitoring receivers. In addition, a monitoring center has been set up to store, classify and localize the data. Furthermore, GIDAS includes a graphical user interface for visualization of results and user control, as well as post-processing and detailed analysis functions.

The main benefits of GIDAS are to improve the secure and robust operation of GNSS receivers, terminals, and GNSS-based applications by providing the ability to reliably detect, classify and localize GNSS jamming and spoofing attacks in real-time. Today, there are already ongoing steps towards a commercial product and first test installations are planned.

The company provided the following testimonial:

"Yes, we managed to build up an international sales network and have managed to get reference installations at airports, road tolling stations, etc... We are continuously working on significant tenders."

5.2.4. EL2-012: Enersyn

Chronos Technology Ltd and the University of Strathclyde, Powerline Technologies Ltd. developed a new type of smartgrid distribution automation sensor platform which uses high speed waveform analysis and high accuracy time stamping to provide electricity Distribution Network Operators (DNOs) with detailed high fidelity information about the operation of their distribution network. The goal was to design the platform in such a way that it provides a flexible infrastructure to support multiple 'apps' in a similar fashion to a modern smartphone. Thus the project included the development of two apps – a micro-PMU (phasor measurement unit) and Non-Intrusive Load Monitoring (NILM) of electric vehicles (EV).

The project has produced a pre-commercial prototype, and a commercially exploitable IP right has been developed. Thus, in a further step, the product is ready to be tested in electricity network trials with electric vehicles. In addition, a business model is being developed, and efforts are being made to register a technology license.

5.2.5. EL2-020: Triband Antennas for Automotive – MISSATO

Together with Taoglas Limited, the MISSATO project developed five distinct GNSS antennas operating on L1/L2/L5 bands on the GPS and Galileo GNSS networks. The overarching goal of the activity was to develop a series of precision GNSS receiving antennas for mobility applications, asset tracking, and general IoT. The products are able to receive L1/L2/L5 GPS/Galileo frequency bands required for vehicular/asset tracking and device management. The antennas were specifically designed for applications requiring cm-level positioning unavailable with older GNSS antennas.

The participation in NAVISP has led to an evolution of the existing products of Taoglas, which were single GNSS band. They used their knowledge of manufacturing and performance and combined the antenna with other products to offer their customers additional options. As a result, the company has managed to develop a new type of antenna as well as new applications for lawnmowers and successfully bring it to market. The success of the activity can for example be seen in the significant growth in robotic lawnmowers and delivery bots solely due to the requirements of multiband GNSS

antennas. Moreover, growth in new applications requiring multiband technology, coupled with the reduced price for multiband modules, has allowed for multiband GNSS antennas adoption.

5.2.6. EL2-037: HAAS, High Accuracy Assistance Service

Rx Network developed with NAVISP a High Accuracy Assistance Service (HAAS). HAAs is a high-precision, cloud-based corrections service, which contains highly accurate corrections for orbits, clocks, ionospheric and tropospheric delays. The use of HAAS will enable horizontal position accuracy of ~50 cm with code phase-based positioning and ~20 cm with carrier phase-based positioning on receivers with external antenna in open sky conditions. HAAS presents new market and customer opportunities for Rx Networks, and the reference network and infrastructure improvements required for HAAS service will also serve to improve and increase the viability of existing products into the future. Furthermore, the company is able to address new markets as for example wearables, drones, mobile robotics or smartphones. Through the project, the company could attract new customers and expand their activities. The company provided the following testimonial:

"Sales collaboration Agreement completed in September 2021 to provide high accuracy positioning to the top OEM smartphone providers. We are currently in early customer engagements phase"

5.2.7. EL2- 049: GBAS Development and Verification

With support from NAVISP, Indra Navia AS, a Norwegian technology and consulting company for the transport and defense sectors, has developed and verified a new ground-based augmentation system (GBAS) Approach Service Type D ("GAST D" in short) ground station technology. This involved the creation of new standards in the field of landing systems, based on satellite technologies, complementary to Satellite Based Augmentation Systems (SBAS).

GBAS measures the accuracy of the received GNSS signals and transmits the satellite corrections, integrity data and approach patterns to the respective aircraft. This allows for improved navigation system performance in the areas of integrity, continuity, availability, and accuracy. So far, this and similar technologies have been used mainly in good weather conditions. However, with the support of NAVISP, Indra Navia AS has developed an operational concept for GBAS GAST D that improves the runway capacity even in low to zero visibility. The term GAST D is used here to refer to landing operations in lower visibility conditions including ICAO Category III operations (ICAO: CAT III). In the long term, GBAS will complement or even replace the mostly used ILS and provide more robust and accurate information to help aircrafts land safely.

By using GBAS GAST D, it will be possible to coordinate air traffic in a more efficient, safer and reliable way even in poor weather conditions, which will not only lead to a general satisfaction of customer needs but also to a reduction of CO2 emissions.

5.3. Success Stories Element 3

Element 3 focuses on participating States' priorities and aims to support their national navigation activities along the whole PNT value chain. Thus, Element 3 provides an opportunity for participating State delegations to initiate and coordinate discussions with national entities and to initiate the processes for identifying and aggregating institutional requirements. The following sub-sections offer

some exemplary activities that demonstrate the successful outcomes of NAVISP collaboration under Element 3.

5.3.1. EL3-001: Maritime Resilience and Integrity of Navigation (MARRINAV)

The MARRINAV project completed in May 2020, assessed the vulnerabilities of PNT in the maritime sector for the UK region and examined a number of technologies complementary to GNSS to mitigate those vulnerabilities.

GNSS has become the principal (and occasionally the only) source of position, navigation and timing (PNT) for ships. On most modern vessels GNSS are deeply integrated within multiple digital systems on the bridge. For example, in portraying the vessel's position and motion on the mariner's Electronic Chart Display and Information System (ECDIS). But many other systems also depend on PNT from GNSS for their position and timing information. These include the current Automatic Identification System (AIS), the future VHF Data Exchange System (VDES) and the whole of the incoming IMO e-Navigation concept. Maritime navigation standards and solutions are evolving to encompass new applications, notably e-Navigation services and marine autonomous systems, including maritime autonomous surface ships (MASS). In the future, they must also consider multi-modal integration of applications as goods flow from the sea, through a port, to the hinterland, to support improved safety, efficiency and environmental protection throughout vital logistics supply chains.

MarRINav has identified feasible and cost-effective technology options within a system-of-systems outline solution architecture to deliver PNT information meeting the performance requirements of maritime users. Preliminary functional and geographic architectures have been described which support the hybridization and fusion of GNSS. The project results have been widely discussed and cited as best practice in numerous national and international fora. In particular the US government (including the US Department of Transportation) and the Canadian Government (Innovation, Science and Economic Development, Canada) have positively referenced the MarRINav findings and/or alluded to the benefits of a holistic systems-of-systems approach. The representative of UK NAIVSP management provided the following testimonial:

"The MarRINav study, has been an excellent example of the use of Element 3, being a project that has influenced national policy making and providing a strong evidence base for decision making."

5.3.2. EL3-002: Cyber Security Test and Evaluation Facility (CYTEF)

In a consortium led by the Royal Military Academy of Belgium, Telespazio Belgium, REHA Group, M3 Systems, Unifly, and Airobot are developing within NAVISP a Cybersecurity Test & Evaluation Facility (CyTEF). The project aims to provide cybersecurity research, test and evaluation services which address the changing threat landscape to the Space and Air Transportation Systems in Belgium, and most particularly possible, state-of-the-art cyber-attacks on UAS command-and-control, payload data and navigation systems. The lead from the Belgian Royal Military Academy provided the following testimonial:

"The development of CyTEF, a test facility for testing the security resilience of drones to cyber and electronic attacks, is of fundamental importance to provide Belgium with one of the most advanced and evolutionary cyber security test range for unmanned vehicle in Europe."

"It fosters the establishment of a national consortium with common goals and helps create a solid foundation to improve Belgian know-how in support to the ambition in the area of cybersecurity systems and services"

5.3.3. EL3-004: Advanced Radio Frequency Interference Detection Alert & Analysis System

The ARFIDAAS (Advanced Radio Frequency Interference Detection Alert & Analysis System) monitoring system was developed under Element 3 by SINTEF, Norway's largest research institute, to provide a high capability low cost solution to the growing threat of disruption of GNSS signals used for critical infrastructure due to intentional and unintentional interference. Current solutions provide very limited spectral coverage that ARFIDAAS addresses by simultaneously covering all current Galileo, GPS and GLONASS signals and providing mechanisms by which threats can be assessed to both enhance detection and alerting while also building a database of known threats. Thus, as a result ARFIDAAS covers the entire GNSS L-band and is designed to send low latency notifications to the site operator containing details of detected RFI events to allow site operators to respond appropriately, while also capturing the events for centralized analysis.

In 2021 the Norwegian Communications Authority (Nkom) located several sources of harmful GNSS signal interference with the help of notifications and reports produced by the ARFIDAAS monitoring stations. The potentially most serious incident involved the apprehension of a jamming device in close proximity to the Norwegian Air Ambulance base in Trondheim. In this case, a jamming device was located by Nkom and the operator fined after the device was detected by a nearby ARFIDAAS station. Thus, through the support of NAVISP a technology was developed, that improves the management of GNSS vulnerabilities significantly.

5.3.4. EL3-005: Trondheimsfjorden Test Area

To address trends in autonomous shipping as a future way of transporting goods and people, NAVISP has partnered with SINTEF and Kongsberg Seatex to establish the Trondheimsfjorden Autonomous Vessel Test Area, which was established in 2016 as the world's first autonomous vessel test area to enable the transition from traditional to autonomous shipping. This project supported the development of infrastructures and methods for testing and verifying technologies and concepts with the goal of ensuring a high level of safety and operability and building confidence in autonomous shipping.

The County Mayor of Trøndelag, has provided the following testimonial:

"Trondheimsfjorden Test Area for Autonomous Ships, a World First of its kind, is a valuable asset for Norway and the development of maritime and ocean space solutions for European and global users. It is a great example of innovative initiatives in the ocean space cluster in Norway and the Technology Capital of Norway, which benefits the whole industry and its users with safe, efficient and sustainable solutions."

This shows the ability of NAVISP to foster the mobility automation and at the same time inspire the development of respective technologies in Norway.

5.3.5. EL3-006: Resilient PNT for the Black Sea and the Danube Region (RIPTIDE)

The concerns about the impact of GNSS vulnerabilities in PNT applications have grown exponentially. In particular in the maritime and inland waterways navigation domain this subject is of utmost

importance, leading to the national initiative RIPTIDE. GMV innovation Solutions S.R.L., together with Romania InSpace Engineering S.R.L., the Romanian Space Agency Research Centre and the Romanian Maritime Hydrographic Directorate, has launched the RIPTIDE project, which is a first phase of the development of a robust PNT solution for the specificities of the Black Sea region and the lower Danube basin. The main ambition of RIPTIDE was to set up the foundations for the development and implementation of resilient PNT in the shortest timeframe.

The Black Sea is an important strategic region for Romania, as well as for the European Union, as it represents a large part of their Eastern borders. This area has a very complex geopolitical context which has encountered in the last years a significant number of situations where the vulnerabilities of the current satellite navigation systems were exploited and led to jamming and spoofing events. As such, RIPTIDE addresses the strategic needs for the as reflected in different national strategies, such as National Security Strategy, National Defence Strategy and the 3S Space Strategy. Furthermore, it is aligned to the needs of the maritime authorities being responsible for the safety of the maritime and inland waterways navigation in the region.

The project has carried out a data collection campaign to assess the criticality of the issue, assessed several resilient PNT technologies suitable for the region and is currently defining a road map for their implementation. Thus, NAVISP, supports activities in order to enable informed decision-making on a national level.

5.4. Preliminary Conclusion

The various projects highlight the scope and diversity of the programme. For example, the presented activities under Element 1 show how NAVISP addresses a wide range of areas in the field of innovation generation. In particular, the programme shapes the scientific state of the art and pushes the frontiers of knowledge. Examples of success stories that significantly influence and drive science forward are the Pulsar timescale and quantum-based sensing for PNT (see section 5.1.2, 5.1.4). This allows technologies to be researched early and technological trends to be anticipated. At the same time, new thematic initiatives can be prepared as for example the project on Earth Moon navigation shows (section 5.1.7).

In addition, once ideas, technologies, and prototypes have been successfully developed, Element 1 opens up the possibility of developing products that can then become part of Element 2. One example is activity El1-011 (Section 5.1.3) which developed a prototype combining GNSS timing from a sparse network of low-cost multi-frequency GNSS stations and time distribution over general terrestrial networks. The prototype is now for continued product development under Element 2 (El2-084), with the aim of eventual commercialization.

Thus, Element 2's set-up goes a step further, not only supporting the development of early-stage technologies, but also preparing solutions for market readiness. Close cooperation with industry also has the effect of strengthening the economy in general, but in particular of increasing the competitiveness and chances of success for individual companies. This can be seen for example in activity EL2-007, where a product was developed from design to prototype, which is now used worldwide (see 5.2.2). Often, the products developed could additionally complement the portfolio of the respective company. For example, TAOGLAS developed in several projects under Element 2 a range of precision GNSS receive antennas for automotive, mobility applications, asset tracking, and

general IoT, which significantly expanded their product range (see for example 5.2.5). The company therefore used its knowledge of manufacturing and performance and combined the antenna with other products to offer its customers additional options. By developing new products and expanding the portfolio, it was also possible for some of the activities to attract new customers and thus gain a larger market share (see for example 5.2.6). Thus, a large proportion of the completed projects under Element 2 were able to develop products that could be commercialized directly or were about to be commercialized in the following months after the activity was closed. Success indicators included addressing and reaching new markets and new customers as well as increasing market share and profits.

Lastly, activities under Element 3 complement and complete the NAVISP programme by not only fostering the European PNT industry but also by increasing the national awareness and capabilities by supporting PNT national programmes and relevant institutional activities. For example, activities in Element 3 demonstrated how GNSS vulnerabilities can be addressed at the national level in order to manage them effectively (see 5.3.3). In addition, national initiatives improved PNT's resilience in key strategic areas, enabled informed decision-making and thus influenced national policy-making (see 5.3.5). Moreover, special application focus was placed on maritime applications and initiatives, as these usually transcend private actors and are of economic but also political relevance for the public sector. The MARRINAV project (5.3.1) for example influenced national decision making by assessing the vulnerabilities of PNT in the maritime sector for the UK region and examining a number of technologies complementary to GNSS to mitigate those vulnerabilities. The Trondheimsfjorden Test Area for Autonomous Ships (5.3.4) in turn, enabled the development of autonomous maritime and oceanic solutions for European and global users by providing the world's first test area for autonomous vessels. Thus NAVISP supports not only maritime resilience but also mobility automation.

In conclusion, the division into three elements, each with a different focus, allows NAVISP to address the innovation process in a holistic way. The exemplary success stories from Element 1 demonstrate that activities with a high degree of innovation that focus on mitigating technical risks and maturing new PNT technologies are particularly promoted. Element 2, on the other hand, supports a balanced mix of activities using mature and novel PNT techniques with the corresponding focus on mitigating market risk (mature techniques) or technical risks (novel techniques) in products at early stages of their development. Element 3 complements the other two elements by supporting activities of transversal benefit at national level with focus on support to retirement of regulatory risks by introducing new PNT techniques (i.e. GNSS) in existing markets. This structure allows NAVISP to cover the entire PNT value chain, enhancing the PNT industrial capabilities of ESA Member States while promoting jobs and growth in the space sector.

6. NAVISP Implementation Efficiency

6.1. Element 2 Time- to- Award Contract

6.1.1. Element 2 Procurement Process

The tendering process in Element 2 follows a two-step approach:

- Submission of Outline Proposal: the Tenderer submits an Outline Proposal. After a positive assessment and consultation with the relevant Delegation, ESA invites the Tenderer to submit a Full Proposal.
- Submission of Full Proposal: the Tenderer submits the Full Proposal, including the Letter of Support of the Delegation. After a positive evaluation of the Full Proposal, ESA will invite the Tenderer to negotiate and will then award the contract to the Tenderer by committing the relevant funds.

Since the "business-oriented" nature of the activities of Element 2 and the scope to attract companies out of the traditional space sectors and even approaching ESA for the first time, a lean and efficient procurement process is of utmost importance. The Implementing Rules refer indeed to a 4months target timeframe from Outline Proposal to Funds committed.

To closely monitor the efficiency of the procurement process, the procurement cycle is broken down into four main steps, each one with different "Responsible".

- **Step 1: Submission of Outline Proposal by Tenderer, assessment by ESA and the relevant Delegation** *(this step goes from the time of Outline Proposal submission to the time when ESA invites Industry to submit the Full Proposal).*
  Responsibility for the efficiency of this step is shared between Industry (poor quality of the Outline Proposal requiring interaction with ESA for clarifications), ESA (assessment of Outline Proposal) and the relative Delegation (green light to proceed).

- **Step 2: Submission of the Full Proposal by Industry** (*including LoS by Delegation*).
  After the consequent authorization to proceed, the Economic Operator is requested to submit the Full Proposal. The responsibility for this step resides in the Economic Operator and the relevant Delegation for the provision of the LoS.

- **Step 3: ESA evaluation of the Full Proposal**
  Once the Full Proposal is submitted to ESA together with the LoS, ESA assesses the Full Proposal. This step is fully under ESA responsibility.

- **Step 4: Negotiation process and contract award**
  Once the evaluation is completed, ESA negotiates with the Economic Operator to award the Contract. Responsibility for this step is shared between ESA and the relative Economic Operator (quality and completeness of the Full Proposal implying interactions before contract award).

To each of the steps above, a target duration was assigned in order to fulfil the overall objective of four months. These are the following

- **Step 1:** 10 calendar days
- **Step 2:** 30 calendar days
- **Step 3:** 40 calendar days
- **Step 4:** 40 calendar days

The ideal procurement model is provided in Figure 26.

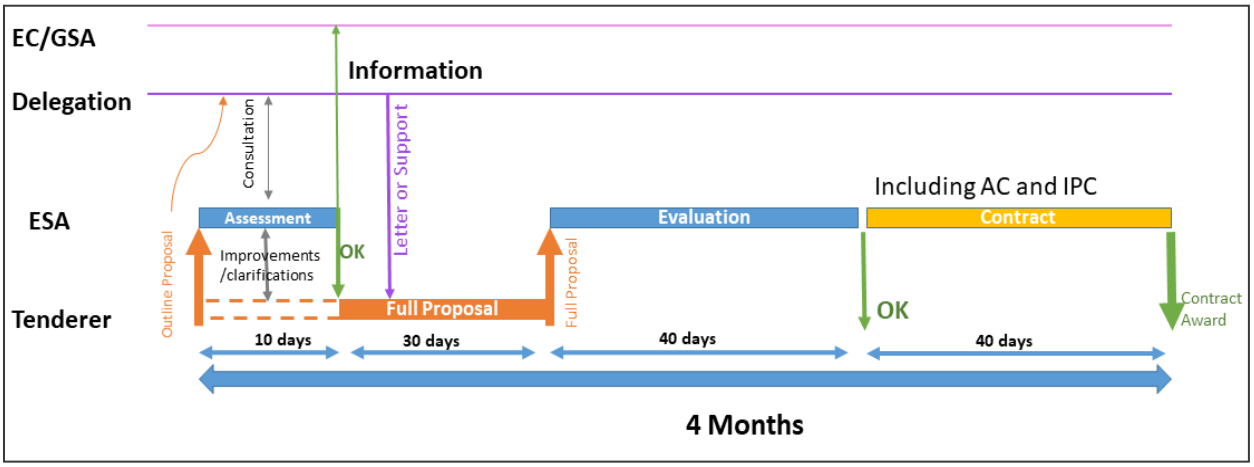


Figure 26: Model of the ideal Procurement Process

The objective of 4 months is a challenge within ESA environment. The efficiency of the process is impacted by different factors. These are:

- The quality and completeness of the Outline Proposal and the Full Proposal that are prepared on the basis of Guidelines and Templates provided by ESA and that can imply delays for revision/clarification/re-submission,
- The time for the Industry to prepare and submit the Full Proposal, prepare clarification to negotiation points and availability for negotiation meetings
- The internal procedures at ESA, the availability of persons to perform the evaluation and for the decision meetings (TOB, TEB meeting and negotiation meeting),
- The availability of the Letter of Support to be provided by Delegations
- The availability of the persons for the meetings.

Some measures were taken from the beginning of the implementation to design a lean and agile procurement process:

- For the quality of Outline and Full Proposals:
  - Simplified Outline and Full Proposals structure and content with detailed guidelines and templates available now on ESA-STAR under CfP AO10516
  - Interaction with Tenderers before submission
  - Mail address available for clarifications.

- For ESA procedures:
  - Adoption of the simplified tools available at ESA (ESA STAR, virtual meetings, etc.)

- For the availability of the persons:
  - Optimization of the planning of TEB (notification by the company 15 days in advance of the date of the intended submission of the Full Proposal), planning negotiation meetings well in advance, etc.

6.1.2. Element 2 Procurement Process KPIs

In accordance with the different steps defined for the Procurement Cycle and with the objective of monitoring and controlling the actual times of the different activities with the model, the following Key Performance Indicators have been created and tools put in place to track each step and sub-step of the procurement process.

Procurement KPIs	
KPI	**Description**
KPI #1 to measure Step 1	Calendar days between Outline Proposal reception and ESA feedback to the Tenderer. Objective: 10 Days
KPI #2 to measure Step 2	Calendar days between ESA feedback to the tenderer and Full Proposal reception (and Letter of Support). Objective: 30 Days
KPI #3 to measure Step 3	Calendar days between Full Proposal (and Letter of Support) and TEB report. Objective: 40 days
KPI #4 to measure Step 4	Calendar days between TEB report and contract award. Objective: 40 Days
KPI #5 to measure overall procurement time	Calendar days between Outline Proposal reception and contract award. Objective: 120 Days

Table 4: Procurement KPIs

6.1.3. Element 2 Procurement Process KPIs Result and Analysis

In the first NAVAC report, the results and the analysis on KPIs were referring to a total of 25 activities out of the 47 in the pipeline at that time (12/2019), which had completed the Procurement Cycle.

A second analysis was carried out on the 55 contracted activities:

- Contracted activities IDs from 052 to 120
- Activities IDs before ID052 but contracted after 12/2019

The results show a very wide range of cases, some of which present significant peaks. The following tables report the KPI values, including the peaks:

Procurement Stages	KPI #1 Solar days between outline proposal reception and ESA response to the Tenderer	KPI #2 Solar days between ESA feedback to the tenderer and full proposal or letter of support reception (the latest)	KPI #3 Solar days between full proposal or letter of support (the latest) and TEB	KPI #4 Solar days between TEB and funds committed (4A+4B)	KPI #5 Solar days between outline proposal reception fund committed
Ideal Number of days	10	30	40	40	120
Average number of days	36.24	101.75	43.07	66.31	247.36
Delta (days)	26.24	71.75	3.07	26.31	127.36
DELTA %	**262%**	**239%**	**7.5%**	**65%**	**106%**

Table 5: KPIs Element 2 (Delta in %)

By eliminating the peak cases to avoid biasing the statistics too much, the results are more promising although still showing a significant margin for improvement:

Procurement Stages	KPI #1 Solar days between outline proposal reception and ESA response to the Tenderer	KPI #2 Solar days between ESA feedback to the tenderer and full proposal or letter of support reception (the latest)	KPI #3 Solar days between full proposal or letter of support (the latest) and TEB	KPI #4 Solar days between TEB and funds committed (4A+4B)	KPI #5 Solar days between outline proposal reception fund committed
Ideal Number of days	10	30	40	40	120
Average number of days	14.20	29.82	40.16	56.71	140.89
Delta (days)	4.20	-0.18	0.16	16.71	20.89
DELTA %	**40%**	**0%**	**0%**	**41%**	**17.4%**

Table 6: Improved KPIs

Main causes for the remaining delays are:

- KPI1 delays occur mainly due to
  - Outline Proposals to be amended/improved by the Tenderer
  - Delays of the feedback by Delegations to proceed with Full Proposal
- KP2 delays:
  - Companies do not make it to submit Full Proposals in 30 days and/or Delegations to provide the LoS
- KP3 delays (although minimal)
  - Mainly due to unavailability of TEB members
- KP4 delays:
  - Clarifications on Full Proposals require multiple interactions with companies, implying extra meetings to be scheduled.
  - Contract Office support has been reorganized

Margins for improvement:

- **Companies**
  - request the prime to interact with Delegation at this very first stage

- fully satisfy the requirements and guidelines for Full Proposal preparation

- **Delegations**
  - simplify the procedures to provide the LoS (some Delegations go through a national selection process, etc.)
- **ESA**
  - create a template for Outline Proposal
  - reinforce the Contract Office
  - further simplify the Full Proposal requirements
  - reinforce planning of negotiation date with TO, CO and Industry

7. Key Findings

Based on the above analysis of NAVISP activities up to and including 2021, various conclusions can be drawn. The following section is divided into Key Findings, which are then discussed in more detail. A comparison is made to the 2019 Report and key challenges as well as success factors are identified and highlighted.

KF-1: Consolidation of the success of NAVISP during Phase 2

The scope of the programme and pace at which projects are launched demonstrate that NAVISP is a success among the European PNT stakeholders. Both Member States and Industry are willing to engage and contribute. The level of industry co-funding is a success.

KF-2: Confirmation of the general findings of the NAVAC's 2019 assessment

The key findings made in the NAVAC's 2019 assessment are still largely valid. In general, what was going well is still doing so (or even better) and the weaknesses and gaps identified still exist. The ambition to encourage more market-pull and less technology-push has only partially been realised. NAVAC believes that this reflects the nature of ESA.

The ambition to encourage more market-pull and less technology-push has only partially been realised.

ESA can convene the skills, technical expertise, industry partners and Member State delegations in a way no other organisation can. It is a strength and at the heart of the "ESA brand". Commercialisation and market skills should not be seen as gaps within ESA's capabilities but as opportunities for the industrial and commercial partners to do more.

Some of the findings of the 2021 NAVAC's assessment are of general nature and apply to all the Elements of the programme.

Large companies to be encouraged to benefit from the innovative capacity of small companies.

Large companies still consume a substantial part of the programme budget, especially in Element 1 and Element 3, funds for SMEs and University/Research institutes being relatively small. More needs to be done to encourage large companies to draw on the knowledge, innovative ideas and skilled personnel in these smaller organisations. It is why these projects are collaborative. The benefits will come in the quality of the science, engineering, and innovation in the project outputs.

Non-space system integrators still not engaged in NAVISP.

In addition, there is little engagement from European non-space system integrators in the programme, despite the recommendations made by NAVAC to widen its endeavours.

Regardless of the NAVAC REC#12 in 2019, the average size of the activities undertaken is still relatively small, i.e. roughly 500 K€ per activity in Element 1 and 800 K€ in Element 2. Other weaknesses identified in the programme may be because costs are prohibitive.

The size of activities is still small.

To give two examples, certification and the mitigation of regulatory risks, and IP protection can both be costly. It may not be feasible to achieve a balance within the scope of the programme and the

solution may lie in working with other funding bodies, including industry which could be encouraged to contribute its share of co-funding.

In this update of the 2019 report, the granularity of the analysis of the activities in terms of sectors concerned, challenges or objectives addressed, or position within the value chain has been increased which allows a deeper insight on the actual performance of the programme vis-à-vis its goals.

KF-3: Despite efforts made in Element 1 to facilitate the transition from technology advancements to commercial products, more progress is needed on key technology development to prepare commercialization or in the reduction of regulatory risks

NAVAC agrees that Element 1 must be technology driven, and this goes along pretty well with the distribution of the activities undertaken within this Element shown in Figure 2. Furthermore, the increase of the relative weight of proof-of-concept and demonstration activities (see Figure 3) with respect to 2019 results goes in the right direction, although there is still room for improvement to bring the results of the projects closer to actual products.

However, as illustrated in Figure 4, NAVISP is not succeeding in introducing existing technologies in new markets (Innovation Cat. 3) and is possibly still spending too much - at least for Element 1 - in bringing existing technologies to existing markets (Innovation Cat. 1). There could be valid reasons why Cat. 3 is taking a decreasing share of Element 1. The element is technology-driven and developing new technologies is therefore the priority. Cat. 3 is more about market pull, which would normally be better addressed within Element 2.

NAVISP support to key technology developments, e.g. GNSS chips, should be strengthened including any opportunities possible within Element 1.

Cat 1 projects must be innovative. If the innovation is not in the technology, it must be shown to be elsewhere in the approach to market. There must be a clear case of innovation being used to improve the competitiveness of the European industry in areas where it is clearly lagging behind other international competitors. For instance, this could be the case for funding European GNSS chips to reduce the dependence on global supply chains. Although this is recognized as more of a task for Element 2 due to its commercial support nature, complementary opportunities should also be considered in the Element 1 workplan.

Figure 6 and Figure 7 clearly show that the emphasis within Element 1 is placed on mitigating technical risks, which does not come as a surprise being essentially a technology driven element and relying on work plans prepared by ESA. Some market risk mitigation may lay hidden under some activities, but the fact that market risks rank low in the Element 1 priorities is of little concern, since the industry can resort to Element 2 – which in fact receives the largest part of the funding – for managing market risk.

Reduction of regulatory risks should receive more attention in Element 1.

However, regulatory risks should receive higher attention in Element 1. The maximum duration of two-year considered so far in the definition of Element 1 activities. This may disadvantage projects addressing regulatory risk as they can take longer as they often involve the collaboration of many parties. Consideration should be given to this in the annual work plans.

KF-4: Element 2 has continued to be a very attractive Element to industry, namely for technology risk reduction on their products

As for Element 2, Figure 8 shows a good split of programme funds between large companies, SMEs, as well as university and research centres. Very good progress has been also reached in attracting new entrants to ESA and companies not yet interested in exploiting space-enabled technology.

The success of Element 2 in attracting interest of newcomers to space-enabled technology solutions should be continued and strengthened.

This is positive and it is recommended to further pursue these efforts. Attracting newcomer companies to develop downstream space-enabled PNT products technology will bring a fresh and perhaps more accurate perspective to the needs of the PNT market. It also opens up opportunities for spin-in/spin-off technology effects.

Consideration (in consultation with national delegations) should be given to:

a) Further improve programme outreach to other sectors, and
b) Prioritize the participation of SME and non-space players could be considered

The funding by product position within the industry value chain (Figure 9) is in general evenly distributed, with the largest share of funds requested for PNT receiver products. This is an indication that industry continues to believe that improvements on PNT receivers are required, whether in terms of weight, power and cost reduction or performance (antenna, sensor integration, etc..). This distribution of funds is considered in line with the NAVISP objectives. It is indeed the indication that the PNT receiver is the fundamental building block of any PNT system, allowing the reception of the PNT signals (GNSS or other Systems) and providing a PNT solution: improvements are required to be competitive on the market and satisfy the increasing expectations in terms of performance such as accuracy, integrity, robustness but also in terms of reduction of weight, power, and cost.

NAVISP should take advantage of the new Galileo services to increase its outreach in professional markets.

As concerns the markets targeted by Element 2 activities, the 2019 recommendations appear to have had some positive impact in this respect, but it is still insufficient. This may have to do with the community awareness about NAVISP. Outreach actions may have attracted companies beyond the "usual suspects" in the space sector. However, the professional markets (agriculture, surveying, geomatics, and construction) are still underrepresented, although Europe makes efforts in the Galileo implementation for these markets (HAS, Authentication: OSNMA + CAS).

From the analysis of the distribution of funds with respect to the challenges or objectives addressed (Figure 11) it can be noted that with a few exceptions (e.g. space market sector) industry requires NAVISP Element 2 support to reduce technical risks, i.e. performance improvements. This is further confirmed in Figure 14, which presents the view of ESA experts on this matter and Figure 23, which presents the industry view. This was a characteristic observed in the 2019 assessment and not much has changed (Figure 15). It is interesting also to note how the analysis presented in **Error! Reference s ource not found.** provides a picture of what the main concerns of the different market segments are in relation to PNT, e.g. for the critical infrastructure sector, the main interest is how to improve the performance in robustness and resilience, while for the sector of space PNT products, the main issue is optimisation of proven techniques. It is also surprising how little is spent on industrialization, for an

Element that is supposed to deliver products close to the market. This also points out that technology risks are also the primary concern of Element 2 activities, by (too) far and large.

All these data confirm the understanding that companies are using the program to fund "high-risk investments" in technology, rather than to improve the competitiveness of existing products. This is neither good nor bad, but speaks loudly about industry priorities: the European industry does not seem very concerned about catching up with international competitors, even in highly profitable segments of the market (e.g. consumer market), but rather with capturing future potential "blue oceans". Market risk mitigation still takes a small share of the funding for what we would expect.

Element 2 is currently biased towards technology risk reduction while reduction of market risks is not yet fully exploited.

The question is therefore whether or not NAVISP can do something to reduce the gap in those existing market segments where the European industry is lagging behind. Thematic calls for proposals can help but may not be the only solution.

KF-5: Element 3 has been successfully consolidated during Phase 2.

The funding of Element 3 has drastically increased in the second Phase of the programme, demonstrating the interest for the Member States to use this ESA programmatic tool to support their national priorities. Besides, Element 3 distribution of funds is, broadly speaking, better aligned with the objectives of this Element: the largest part of the funding goes to develop new technologies to address national needs and is more or less evenly distributed among mitigating technical and regulatory risks, while market risks-which are sensibly left to industry under Element 2-are addressed only marginally. Most of the countries participating in Element 3 do not have a large national navigation programme. It may be worth exploring ways to align this Element to the specific interests of those member states that do not have significant national navigation programmes.

KF-6: The current design of the industry survey among actors of Element 2 activities is good and reveal valuable insights to better direct the actions of the programme

The 2019 assessment included an online survey of Element 2 companies to capture perceptions about the programme from an industry perspective, as this element of NAVISP is industry-driven. The representativeness of that survey was somewhat limited as the response rate was lower than expected, perhaps due to the fact that the programme was still relatively new (2 years) and there were not as many companies involved.

For this update of the assessment, the online survey with the same set of general questions has been repeated, this time including a larger number of companies since the programme is now 5 years old. In addition, the general online survey has been complemented with one-to-one interviews with the primes of the completed projects to better understand the benefits that the NAVISP support has provided and i.e. whether the original commercial perspectives of the project where met.

The combination of the two survey types, as well as the larger number of companies surveyed, should provide a more representative picture of the industry's perspective than the 2019 assessment. It has also allowed to have more detailed insights. ESA is therefore encouraged to continue conducting these surveys on a regular basis.

The current results highlight some important facts:

Flexibility in the end-to-end procurement process is key

The industry calls for flexibility to "incorporate changes retrospectively" (or more generally for further flexibility). This is important to adjust the projects to the actual market demands. The understanding of the market needs may vary along the project execution, especially if the complete process from project inception into the programme to the actual implementation takes a long time, as is often the case. NAVISP should provide some flexibility, of course, within reasonable limits to ensure that projects do not deviate entirely from what national delegations were willing to support, to adjust the project objectives over time.

ESA should find ways to support industry even in market knowledge

ESA market chain knowledge and networking capabilities are rated on the low side. This is not necessarily a surprise. Non-space stakeholders tend to know their own industry much better than ESA, so these actors tend not to appreciate ESA's support in this regard. However, ESA can ease the transfer of knowledge across sectors and help the non-space companies from a specific sector to benefit from lessons learned, market demands or viewpoints from other sectors. Moreover, ESA can also invite experts from other sectors to project reviews after previous consultation with the companies to preserve the required confidentiality. This could also be one of the reasons why mitigating market risks is not the highest priority among companies asking for support in Element 2.

Knowing in the industry proposals, the target Innovation Category and risks to be mitigated would facilitate the monitoring of NAVISP objectives

The replies to the questionnaire show that the industry has a different view of the risks mitigated by the activities that they undertake than NAVAC's. This may be due to the fact that the emphasis in the declared project objectives is on technical matters, in the belief that this will help gaining ESA approval for funding, but this is just a reasonable guess and needs to be confirmed. It should be interesting to ask the industry beforehand what is their own view of the risks that they intend to mitigate, or the Innovation Category they are aiming at.

NAVISP support for developing IPR would increase the IPR generated in the programme

The report states that only one company was able to develop IPR from their project. This is definitely below expectations. It is important to find out whether this is because the projects did not produce protectable results or because the companies developing IP rights could not afford to protect them. The fact that most companies find support in this regard interesting points to the second. It is recommended that NAVISP incorporates mechanisms that allow supporting SMEs (large companies do not need this support) in the protection of the IPR generated within the scope of the programme.

Tracking of product evolution is important to better understand the success of NAVISP

A clear concern for NAVISP in the future should be how many programme initiatives make it through the "death valley" of product development and finally become a commercial product. The success stories contained in this report are encouraging, but still only a small percentage of contracts have been closed and the reports are too recent to validate the product evolution. It is important to continue to monitor the evolution of the products developed within NAVISP to obtain a real measure of the return on the investment made. A repetition of the industry surveys at regular intervals (2-3 years) may be an adequate means to achieve this objective.

KF-7: Programme implementation efficiency

Programme implementation efficiency has improved in every metric since the 2019 assessment by NAVAC, which speaks highly of the ESA Executive's management of NAVISP. However, there is still room for improvement. Efforts remain to be made in the areas of procurement process and time to contract. ESA cannot do this alone. The involvement and support of the national delegations by, in some cases, simplifying the delegation's internal processes will be of great help in this respect for Element 2. As for Element 1, the implementation of mechanisms in the programme such as the "opt-out" of Member States for some specific activities after the approval of the annual work plan can also simplify the processes and further encourage the submission of competitive bids.

8. Recommendations

Most of the recommendations made in NAVAC's 2019 assessment are still valid. However, some clarifications and precisions can be added:

- Thematic calls have demonstrated to be an effective mechanism to rebalance the distribution of funding among areas of interest, to raise the awareness about the programme in some communities and to catch the attention of non-space players. It is recommended to launch additional thematic calls in areas of choice, e.g. "Inertial Technology in Europe", i.e. MEMS sensors, optical sensors, quantum-based sensors (both gyros and accelerometers) or low – power, small size IoT technologies. This recommendation can be accommodated as a reformulation of Rec#9 and Rec#10 of the 2019's assessment (see Table 2).
- More efforts should be made to fill the gaps in the European technological base for PNT systems, e.g. funding of European GNSS chips, reduce the dependence on global supply chains (Asia, USA). Although due to the commercial interest of these technologies most of the support is expected to be realized through Element 2, any opportunities possible within Element 1 should also be considered in order to encourage industry to make the necessary investments.
- Reconsider the level of funding per activity, and whenever possible increase it in order to improve the effectiveness of the public investment. Although it is recognized that level of funding is also an industry responsibility in co-funded projects, this recommendation is taken up by strengthening the already existing Rec#12 addressed to the Participating States.
- Reinforce outreach actions, possibly by taking joint actions with other public bodies, industry associations or institutions, to raise awareness about NAVISP potential to fund actions concerning areas presently underrepresented in the programme, e.g. mitigation of regulatory risks. For example, promote and contribute to joint industry events organized by ERTICO to address the issue of certification in autonomous driving, or by EASA in air navigation. This recommendation is taking up with a revision of the existing Rec#7.
- Place emphasis on achieving a higher industrialization level in Element 2 activities. This was already recommended in the 2019 assessment (Rec#6) and in this update, the recommendation is maintained and reinforced.
- Notwithstanding a measured balanced risk in running activities, the ESA Executive is encouraged to implement a higher research culture in NAVISP by stretching the scope of activities, for example by including high risk activities definition, Thematic Calls and/or taking up higher risks on the procurement process (e.g. risk-friendly payment plans). Some flexibility in adapting project objectives to improved or changing perceptions of market needs will also be appreciated. This is a new additional recommendation.
- The existing recommendation (Rec#11) calling for efforts to involve non-space primes in the programme is still maintained with a word of caution that this should not come at the expense of the inclusion of non-space SMEs, which at the moment is quite satisfactory.

- Incorporate mechanisms that allow supporting SME in the protection and exploitation of the IPR generated within the scope of the programme. This is a new additional recommendation.
- Devise some mechanisms to improve market knowledge and networking support in non-space sectors. Cooperation with other entities would bring benefits, recognizing that industry has the required expertise. Trade associations could play a useful role. This aspect will be covered in the reformulation of Rec#7.
- The ESA Executive is encouraged to continue with the realization of periodic industry surveys within the Element 2 companies in order to assess the commercial success of the products supported by NAVISP.
- Participating States are encouraged to simplify the internal processes for issuing Letters of Support so that:
  - Letters of support could be issued more rapidly for Element 2 projects as time is critical for commercial activities.
  - Competition is further enhanced for Element 1 bids, i.e. for Element 1 to exploit the opt-out function to avoid the LoS
- Finally, NAVISP shall be a tool to prepare the way towards future innovative satellite navigation systems having in mind a market perspective and in concert with EGNSS evolutions. Developing and testing some basic technologies in a way that allows to improve the definition of requirements for future systems will support this effort without interfering with the role of other organizations which would allow to support the European GNSS ambitions. This is a new additional recommendation.

The full list of recommendations is summarized in Table 7. Of the total of 24 recommendations, 12 have been retained from the 2019 assessment, 5 recommendations, highlighted in green, have been revised and 7 new recommendations, highlighted in orange, have been added.

Recommendations 2022	
ID	**Description**
1	To maintain and if possible widen the non-GNSS centric view of NAVISP with the objective to enhance the robustness of the user's position, navigation and time determination. This could be achieved by: ○ Element 1: maintaining a high percentage of the work plan budget devoted to R&D on non-GNSS centric activities. ○ Element 2: organizing dedicated calls to non-GNSS centric activities Examples of non-GNSS centric activities include the development of multi-sensor PNT solutions where GNSS is not the main sensor, e.g. image and terrain-based navigation and in general any activity aiming to mitigate the vulnerability of GNSS to jamming and spoofing.
2	ESA to encourage the participation of a wider number of member states to Element 1 due to the positives effect on competition.
3	To retain the current structure of NAVISP focusing on innovation, competitiveness and national strategies since it fits the general interest and affinities of the stakeholders in the Programme.
4	ESA is encouraged to monitor the capability of Element 1 to generate follow-on industrial initiatives in the PNT sector.

5	ESA to include in Element 1 Workplans more activities aimed to reduce regulatory risk related with the introduction of existing PNT technologies in new markets/domains. Proof-of-Concept or demonstration activities would go in this direction.
6	ESA and participating states should further encourage the submission of proposals to Element 2 aiming to reduce market risks by strengthening the requirements on industrial/product maturity of the outputs of the activities.
7	ESA is encouraged to strengthen the relationship of the programme with other public bodies, industry associations or institutions in order to improve the effectiveness of the programme in achieving its objectives and in particular: • to highlight the opportunities of the programme to support the reduction of technical, market and regulatory risks and, • to improve the programme market knowledge and its networking support in non-space sectors
8	ESA and the participating States are encouraged to discuss with non-space European key players in the GNSS/PNT markets in order to understand how to make the Programme more appealing to their participation.
9	ESA is encouraged to pursue the instrument of Thematic Calls shall continue to be pursued in order to rebalance the distribution of funding among the areas of interest and to raise awareness about the programme in some communities including non-space players.
10	2019 recommendation Integrated in revision of recommendation #9.
11	ESA and the participating States are encouraged to discuss with system integrators (primes) that are entering in the PNT market but whose primary business is not space related, about the opportunities that NAVISP may offer to their activities.
12	Participating States to Element 2 are further encouraged to consider increasing the budget per activity to increase the effectiveness of public investments so that projects can lead to more mature outputs from the industrial product point of view.
13	ESA to consider the inclusion of mechanisms in the Element 2 current procurement process allowing to better control the time taken by companies to prepare full proposals and the time to obtain the required letter of support.
14	ESA is encouraged to continue its networking efforts and in particular the regular organization of NAVISP industry days were stakeholder in the Programme could meet and share experiences and results.
15	ESA to consider, within the limits of due diligence, further simplification of the procurement process to allow reducing even further the time required to place contacts in Element 2, in particular, for those activities where the main focus is to reduce the market risk.
16	ESA is encouraged to promote cross-fertilization among Element 3 activities by for example, organizing workshops on common topics.
17	Participating States are encouraged to simplify the internal processes for issuing letters of support so that: • letters of support could be issued more rapidly for Element 2 projects as time is critical for commercial activities • competition is further enhanced for Element 1 bids
18	ESA is encouraged to incorporate mechanisms that allow supporting SME's in the protection and exploitation of the IPR generated within the scope of their activities.
19	ESA is encouraged to continuously monitor the level of innovation and risks mitigated by the activities in the programme to provide an up–to-date assessment of the achievement of the objectives of the programme.
20	NAVISP support to key PNT technology developments, e.g. GNSS chips, should be strengthened including any opportunities possible within Element 1 in order to encourage industry to make the necessary investments.
21	The ESA Executive is encouraged to implement a higher research culture in NAVISP by stretching the scope of activities, for example by including high risk activities definition, Thematic Calls and/or taking up higher risks on the procurement process (e.g. risk-friendly payment plans).
22	The ESA Executive is encouraged to continue with the realization of periodic industry surveys within the Element 2 companies in order to assess the commercial success of the products supported by NAVISP.

23	Participating States are encouraged to simplify the internal processes for issuing Letters of Support so that: • Letters of support could be issued more rapidly for Element 2 projects as time is critical for commercial activities. • Competition is further enhanced for Element 1 bids, i.e. for Element 1 to exploit the opt-out function to avoid the LoS
24	NAVISP shall be a tool to prepare the way towards future innovative satellite navigation systems in concert with EGNSS evolutions.

Table 7: Updated List of Recommendations following the 2021 Assessment, "blue": recommendations maintained, "green": recommendation revised, "orange": new recommendation

9. Conclusions

Five years upon its inception, NAVISP is meeting its original objectives and, in many aspects, exceeding expectations. The programme has not only invested around €100 million, but leveraged industry investment for over 30 additional millions of euros. The activities undertaken spread along the whole PNT value chain, and score high in technological innovation. NAVISP has managed to engage companies and organizations coming from both space and other sectors, and has helped many SMEs to break their way into the market, create new jobs and develop new products. The Participating States has also benefited from NAVISP by improving their national PNT infrastructures and supporting their industry. At this point in time, NAVISP can also boast quite a few success stories, and it is fair to expect some more to materialize as more ongoing projects conclude.

When the Committee made its assessment of the programme back in 2019, we made eight key findings and formulated fifteen recommendations. In our 2022 exercise, we can still hold valid most of our findings and recommendations. The programme strengths remain, but some of the weaknesses that we identified two years ago still stand.

NAVISP Element 1 is a strong engine for innovation in the PNT field. This Element is, and should remain, technology driven, although effort should be made to give this element a commercial twist by bringing the results of the projects closer to actual products, possibly via Element 2 implementation. Supporting key technology developments, as for instance GNSS chips, that help the European industry to level the field with their international competitor and to reduce its dependence with respect to global supply chains also merits some more room within this Element. As does addressing the reduction of regulatory risks that are, in many cases, not clearly perceived by industry.

Element 2 has been extremely successful in capturing the industry attention, including non-space companies. This is a powerful asset to the programme. It clearly levers the market pull and opens new grounds for cross-fertilization between sectors. However, Element 2 is still strongly biased towards mitigating technology risks and not fully exploiting the opportunities that the programme offers to reduce market or regulatory risks. Although this Element is industry driven – and they probably know better what they need –, we deem it worthwhile implementing some adjustments through mechanisms like the already proven thematic calls for proposal.

The Member States have evinced their interest in Element 3 in the clearest possible way: by increasing its funding. This Element has proven to be a very useful tool for Participating States that do not have a large national navigation programme, but not just for them. The activities undertaken are very well aligned with what NAVAC expect to be the national priorities for this Element: fostering the development of new technologies for assuring PNT resilience and mitigating regulatory risks with PNT test-beds, leaving to the industrial initiative to address the market demands through other Elements of the programme.

The survey undertaken by ESA shows that, broadly speaking, NAVISP scores high in industry appreciation. Of course, there are some shadows, but the results of the survey speak loudly of the procurement process, recognize the programme contribution to the companies' growth and give credit to ESA's technical expertise and support.

NAVAC also acknowledges the efficiency of the NAVISP implementation. There is still margin for improvement, but it has improved by all metrics since our previous assessment. ESA must keep

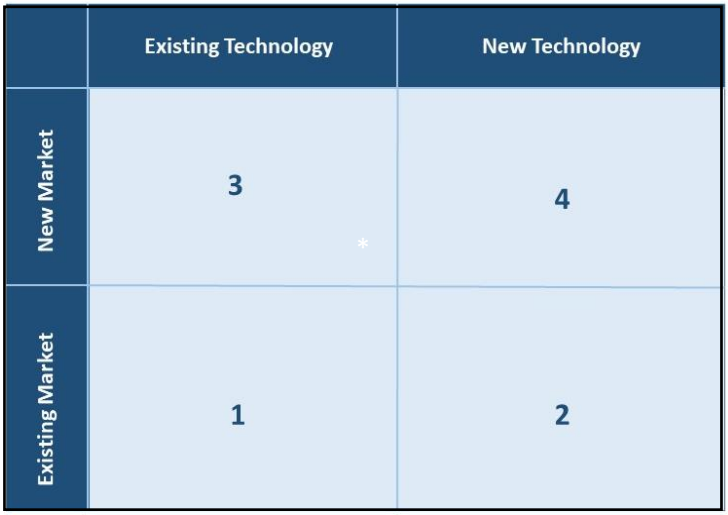
pursuing this endeavor in the next Phase, but cannot do it alone. The cooperation of the Participating States by simplifying their internal processes as far as possible will greatly aid further enhancement in this respect.

Notwithstanding the very positive outlook that we have on the programme status, we have proposed some recommendations for improving NAVISP performances and achievements. Quite a few of them are still the same that we made back in 2019, with some nuances, and we have added some others that have been gathered before in this report. Possibly a good summary of our new suggestions to ESA is: capitalize your technical expertise for the benefit of the industry and leverage NAVISP to pave the way towards future navigation systems and key PNT technology developments with a market perspective.

To wrap up, we at NAVAC are adamant that NAVISP has successfully met its objectives this far. The programme has become a key tool to enhance the European competitiveness in the PNT field, and there is a broad margin to do even more. We encourage ESA to chase this chance by preparing for a third Phase for the Programme.

Annex A: Definition of Innovation Categories and Risk Areas

Innovation Categories



Innovation Category			
Category	**Description**	**Innovation Potential**	**Approached by NAVISP**
1	Existing technology in an existing market	Low	No
2	New technology in an existing market	Medium	Yes
3	Existing technology in a new market	Medium	Yes
4	New technology in a new market	High	Yes

Risk Areas

Risk Area		
Risk Area	**Description**	**Indicators**
Technology Risks	Related to technology readiness, ability to deliver the targeted performance, long-term ability to compete with other suppliers	Technology readiness; performance levels and/or QoS (Quality of Service); ability to compete long-term; and ability to integrate with non-space technologies
Market and Business Risks	Related to the uncertainty of commercial success of the technology or business model	Barriers to commercial success; the maturity of new business models with high-risk/high-potential returns; and the ability of companies to implement such models
Regulatory Risks	Related with the difficulty in developing products or services by market regulatory barriers or dominant position of incumbent suppliers	Regulations as barriers to market entry; regulations as barriers to new suppliers; and regulations favoring incumbent suppliers

Annex B: Definition of Element 2 Activity Categories

The characterisation of NAVISP Element 2 products is based on six independent criteria:

1. Position in the value chain
2. Architectural level
3. PNT technology used
4. Functionalities
5. Competitive challenges/benefits expected
6. Market addressed

1. Position in the Value Chain

It characterizes the product according to its position in the value chain of an ideal space mission.

Value Chain Position	
Position	**Description**
PNT Application	Refers to any user segment application that uses PNT services to offer their value proposition to users.
GNSS Performance Monitoring and Interference and Spoofing Detection System	Refers to user segment systems than are focused on the monitoring of the performance of GNSS Systems and in the detection of vulnerabilities for them such as interference and spoofing.
System for Enhanced PNT Service	Refers to systems focused on the provision of any PNT service enhancement beyond the performance defined by the GNSS systems ICDs or industrial state-of-the-art standards
PNT-Enabled Systems/Solutions	Refers to a system that uses the basic output of a PNT receiver to provide additional functionalities to the end user, e.g energy networks synchronization.
PNT Receiver	Refers the building block of any PNT system allowing the delivery of a basic PNT output (e.g. GNSS receiver, other PNT sensors)
Test Tools and Facilities	Refers to equipment, facilities or user segment systems that will allow the test, verification and validation of any PNT product, standardized functionality or prototype including research oriented test beds

2. Architectural Level

This criterion aims at characterising the product according to its position in functional design organization, complexity and dependency on other functional building blocks.

Architectural Level	
Level	**Description**

Technology	Used when the primarily objective of the activity is to prove, with a prototype a specific new / modified technology
Component	Used to refer to an element that will not operate standalone but as an integrating element of a higher level element in a functional architecture of a product. Following generic components are used in the classification: ○ **Processing-Algorithms**: Used when the primarily objective of the activity is to prove with a prototype a specific new / modified technique or data and/or signal/s processing algorithms. It addresses any kind of data and signal processing or algorithms implementation such as for positioning, navigation, integrity, simulation, etc. The further specific meaning will depend on the value chain classification (i.e. it can refer to analog or digital signal processing and as well to a software application module) and will be complemented by the "**functionalities"** criterion defined further on in this document. ○ **Antenna:** Used when the primarily objective of the activity is the signal receiving component of the system. ○ **Front-End:** Used when the primary objective of the activity is to prove with a prototype a specific new / modified design of the signal conditioning and extraction (down-conversion / demodulation).
Unit	Used when the primarily objective of the activity is to develop a self-standing pre-operational product with proved specific new / modified technology and / or new / innovative features.
Assembly	Used when the primarily objective of the activity is to possibly develop and integrate set of components, normally of different domains that will compose a PNT based solution providing a specific functionality (e.g. robust time reference for an specific application in energy domain). It is frequently used when the Value Chain Position is a PNT Solution.
Infrastructure	Used when the primarily objective of the activity is to develop a complete set of components that will compose a distributed system. It is frequently used when the Value Chain Position is defined as PNT Application or for both PNT Systems.

3. PNT Technology used

It characterises the product according to the positioning, navigation and timing technology/ies used.

<**PNT technology**>:

- **GNSS**: Global Navigation Satellite System

- **Alternate PNT** (<5G>): Any PNT technology different from GNSS.
- **Hybrid** (<5G>, <3D>): GNSS + Alternate PNT

If 5G technology is used as positioning technology, the reference (5G) will appear in brackets, which will also signal that the activity was proposed in the frame of the "5G PNT" thematic window.

If imaging sensors, 3D models or HD maps are used merging GNSS positioning, the reference (3D) will appear in brackets, which will also signal that the activity was proposed in the frame of the "Assisted GNSS by Imaging Sensors, 3D Models" thematic window.

4. Functionalities

It characterises the product according to the main functions provided

- **Positioning:** typically receivers and systems (aggregation of receivers) that conform a positioning system
- **Navigation:** in addition to just positioning (e.g. tracking goods), the product builds navigation capabilities (e.g. guiding an automated vehicle or robot, attitude control, navigation engine, etc.)
- **Time:** the product provides a time based functionality or service.
- **Simulation:** The product provides simulation / emulation of PNT systems (e.g. RFCS, 5G, IMU, etc.).
- **Validation:** the product (typically equipment, test beds or s infrastructure) primarily oriented to validate (including verification) specific PNT functionalities

5. Competitive challenges/benefits expected

It characterises the activity according to the challenge addressed and the actual benefit brought to the users.

Benefits/ Challenges/Objectives	
Main Benefits	**Description**
Performance	The benefit is the enhanced PNT performance beyond the one defined by the GNSS systems ICDs or industrial state-of-the-art standards (e.g. reception and / or processing of the GNSS signals, computation of a PNT solution, etc.). It includes PNT accuracy and availability. If the product is a "**PNT Application" ,** this benefit refers to generic operational performance of the target application.
Robustness & Resilience (RoRe)	The benefit is to enhance the robustness and / or resilience of a PNT equipment or user segment system PNT solutions beyond industrial state-of-the-art standards. It Includes protection against interferences (jamming and / or spoofing), as well as continuity and integrity flaws (e.g. detecting and providing warnings or alerts).
Optimization	The benefit is to optimize a similar existing product in terms of re-configurability, flexibility (allowing, either the company to handle a family of different performing products or the users to adapt the product to a wide range

	of use cases), reduction of size, weight, volume, power consumption, and cost, etc., better suited for competing in the market or even opening new market opportunities.
Cost	A special case of an optimized product, when cost reduction is the main target of the activity. The benefit is for the company to optimize the production cost (and eventually the users in price) of the current product (or if new, regarding similar products currently available in the market).
Support Development	The benefit is to provide developers, researchers and manufacturers with functionalities and tools to obtain their goals.
Industrialization	The benefit is to reach an industrialised product ready to market entry
Support to Standardization	The benefit is to support standard evolutions or validation for standardization process in progress.

6. Market Addressed:

It characterises the product according to the market addressed

- Agriculture
- Aviation
- Construction
- Critical Infrastructure Operators
- Emergency Response
- Energy
- Finance
- Food
- Forestry
- Geomatics
- IoT
- Logistics
- Maritime
- Other
- PNT Developers
- Rail
- Road
- Space
- Sports
- Surveying
- Tourism
- Track & Trace
- Transversal Enhanced Services
- Transversal Enhanced Technology

Annex C: NAVISP Element 2 Online Questionnaire

Please enter your name

Please enter your company

Please enter your NAVISP Activity name

1. Procurement Process

Select whether you agree or disagree with the following statements in regards to the procurement process.

The Process was easy to implement	Agree	Disagree
Templates and guidelines for the proposal were adequate		
ESA Executive was supportive and helped to understand the process		
We received timely feedback of the status of our proposal		
The level of resources required by the process was appropriate		

Other areas, i.e. which areas of the process would you improve? (Please specify)

2. Contribution to Growth

Have you hired any new employees to develop this activity (or to replace the resources that you are devoting to this activity)? If so, how many?

Please explain in detail how your activity has contributed to the growth of your company

3. Risk Mitigation

One of the main objectives of the Element 2 of the NAVISP Programme is to reduce the risk to your company in the introduction of PNT products or services. Please select what was the highest risk mitigated through this activity.

	1st mitigated Risk	2nd mitigated Risk	3rd mitigated Risk

Technology Risk: Related to technology readiness, ability to deliver the targeted performance, long-term ability to compete with other suppliers			
Market and Business Risk: Related to the uncertainty of commercial success of the technology or business model			
Regulatory Risk: Related with the difficulty in developing products or services by market regulatory barriers or dominant position of incumbent suppliers			

Please detail on which other way (if any), the activity has contributed to reduce the risk

4. Overall Assessment of cooperation and different ESA supporting tasks

Select whether you agree or disagree with the following statements about your NAVISP activity.

	Agree	**Neutral**	**Disagree**
The amount of work required was small.			
The time to start the activity was appropriate			
The probability of success was higher than in other programmes			
The knowledge of ESA of the project was high			
It was easy to identify the adequacy of NAVISP to my project			
There was enough funding			

If other, please specify

Please rank the supporting acts of ESA using a scale from 5 (very useful) to 1 (not useful)

	1	**2**	**3**	**4**	**5**
ESA technical Expertise					
ESA market knowledge or value chain knowledge					
ESA brand to market the product/technology					
ESA support in networking with other companies up or downstream the value chain					
ESA was flexible to share risks					

Other Comments

Annex D: List of Recommendations

Recommendations 2022	
ID	**Description**
1	To maintain and if possible widen the non-GNSS centric view of NAVISP with the objective to enhance the robustness of the user's position, navigation and time determination. This could be achieved by: ○ Element 1: maintaining a high percentage of the work plan budget devoted to R&D on non-GNSS centric activities. ○ Element 2: organizing dedicated calls to non-GNSS centric activities Examples of non-GNSS centric activities include the development of multi-sensor PNT solutions where GNSS is not the main sensor, e.g. image and terrain-based navigation and in general any activity aiming to mitigate the vulnerability of GNSS to jamming and spoofing.
2	ESA to encourage the participation of a wider number of member states to Element 1 due to the positives effect on competition.
3	To retain the current structure of NAVISP focusing on innovation, competitiveness and national strategies since it fits the general interest and affinities of the stakeholders in the Programme.
4	ESA is encouraged to monitor the capability of Element 1 to generate follow-on industrial initiatives in the PNT sector.
5	ESA to include in Element 1 Workplans more activities aimed to reduce regulatory risk related with the introduction of existing PNT technologies in new markets/domains. Proof-of-Concept or demonstration activities would go in this direction
6	ESA and participating states should further encourage the submission of proposals to Element 2 aiming to reduce market risks by strengthening the requirements on industrial/product maturity of the outputs of the activities.
7	ESA is encouraged to strengthen the relationship of the programme with other public bodies, industry associations or institutions in order to improve the effectiveness of the programme in achieving its objectives and in particular: to highlight the opportunities of the programme to support the reduction of technical, market and regulatory risks and, to improve the programme market knowledge and its networking support in non-space sectors
8	ESA and the participating States are encouraged to discuss with non-space European key players in the GNSS/PNT markets in order to understand how to make the Programme more appealing to their participation.
9	ESA is encouraged to pursue the instrument of Thematic Calls shall continue to be pursued in order to rebalance the distribution of funding among the areas of interest and to raise awareness about the programme in some communities including non-space players.
10	2019 recommendation Integrated in revision of recommendation #9.
11	ESA and the participating States are encouraged to discuss with system integrators (primes) that are entering in the PNT market but whose primary business is not space related, about the opportunities that NAVISP may offer to their activities.
12	Participating States to Element 2 are further encouraged to consider increasing the budget per activity to increase the effectiveness of public investments so that projects can lead to more mature outputs from the industrial product point of view.
13	ESA to consider the inclusion of mechanisms in the Element 2 current procurement process allowing to better control the time taken by companies to prepare full proposals and the time to obtain the required letter of support.
14	ESA is encouraged to continue its networking efforts and in particular the regular organization of NAVISP industry days were stakeholder in the Programme could meet and share experiences and results.
15	ESA to consider, within the limits of due diligence, further simplification of the procurement process to allow reducing even further the time required to place contacts in Element 2, in particular, for those activities where the main focus is to reduce the market risk.

16	ESA is encouraged to promote cross-fertilization among Element 3 activities by for example, organizing workshops on common topics.
17	Participating States are encouraged to simplify the internal processes for issuing letters of support so that: • letters of support could be issued more rapidly for Element 2 projects as time is critical for commercial activities • competition is further enhanced for Element 1 bids
18	ESA is encouraged to incorporate mechanisms that allow supporting SME's in the protection and exploitation of the IPR generated within the scope of their activities.
19	ESA is encouraged to continuously monitor the level of innovation and risks mitigated by the activities in the programme to provide an up–to-date assessment of the achievement of the objectives of the programme.
20	NAVISP support to key PNT technology developments, e.g. GNSS chips, should be strengthened including any opportunities possible within Element 1 in order to encourage industry to make the necessary investments.
21	The ESA Executive is encouraged to implement a higher research culture in NAVISP by stretching the scope of activities, for example by including high risk activities definition, Thematic Calls and/or taking up higher risks on the procurement process (e.g. risk-friendly payment plans).
22	The ESA Executive is encouraged to continue with the realization of periodic industry surveys within the Element 2 companies in order to assess the commercial success of the products supported by NAVISP.
23	Participating States are encouraged to simplify the internal processes for issuing Letters of Support so that: • Letters of support could be issued more rapidly for Element 2 projects as time is critical for commercial activities. • Competition is further enhanced for Element 1 bids, i.e. for Element 1 to exploit the opt-out function to avoid the LoS
24	NAVISP shall be a tool to prepare the way towards future innovative satellite navigation systems in concert with EGNSS evolutions.

Table D-1: Updated list of recommendations following the 2021 assessment, "blue": recommendations maintained, "green": recommendation revised, "orange": new recommendation