STANDARDISATION OF GNSS THREAT REPORTING AND RECEIVER TESTING THROUGH INTERNATIONAL KNOWLEDGE EXCHANGE, EXPERIMENTATION AND EXPLOITATION

STRIKE3

FINAL REPORT

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1 Introduction

1.1 Purpose of Document

This document is the public version of the Final Report for the STRIKE3 project. This document is delivered as part of Work Package 1: Management. This document provides a summary of the work completed within the STRIKE3 project including a review of the main activities, the schedule, milestones and the main project findings, outputs, conclusions and way forward.

1.2 STRIKE3 Overview

The objective of the STRIKE3 project was to develop international standards in the area of GNSS threat reporting and GNSS receiver testing. This was achieved through international partnerships. GNSS threat reporting standards were required to ensure that international GNSS threat databases could be developed. GNSS receiver test standards were required to ensure new applications could be validated against the latest threats. Both standards are missing across all civil application domains and are considered a barrier to the wider adoption and success of GNSS in the higher value markets.

STRIKE3 monitored the international GNSS threat scene to capture the scale and dynamics of the problem and worked with international GNSS partners to develop, negotiate, promote and implement standards for threat reporting and receiver testing. This was achieved through the deployment and operation of an international GNSS interference monitoring network.

1.3 Document Overview

This document is arranged in the following sections:

- **Section 1** (this section) provides an introduction to the document including a high-level overview of the project, applicable and reference documents and acronyms.
- **Section 2** provides a summary of the STRIKE3 project including the project's objectives, approach, milestones, schedule, deliverables and project partners.
- **Section 3** reviews the project's main findings and outputs.
- **Section 4** provides the conclusions of the project.

1.4 References

1.4.1 Applicable Documents

Ref.	Document Title	Document Reference	Issue	Date
AD-1	STRIKE3 Grant Agreement	Grant Agreement Number 687329	-	26/01/2019

Table 1-1: Applicable Documents

1.5 Acronyms

Acronym	Organisation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
KO	Kick Off
NSL	Nottingham Scientific Limited
RFI	Radio Frequency Interference
WP	Work Package

Table 1-2: Acronyms and Abbreviations

2 Project Summary

2.1 Approach

Within the STRIKE3 project, ten work packages were completed. With regards to the approach taken to ensure that the work completed met the project objectives, the following figure demonstrates the various phases of the project work.

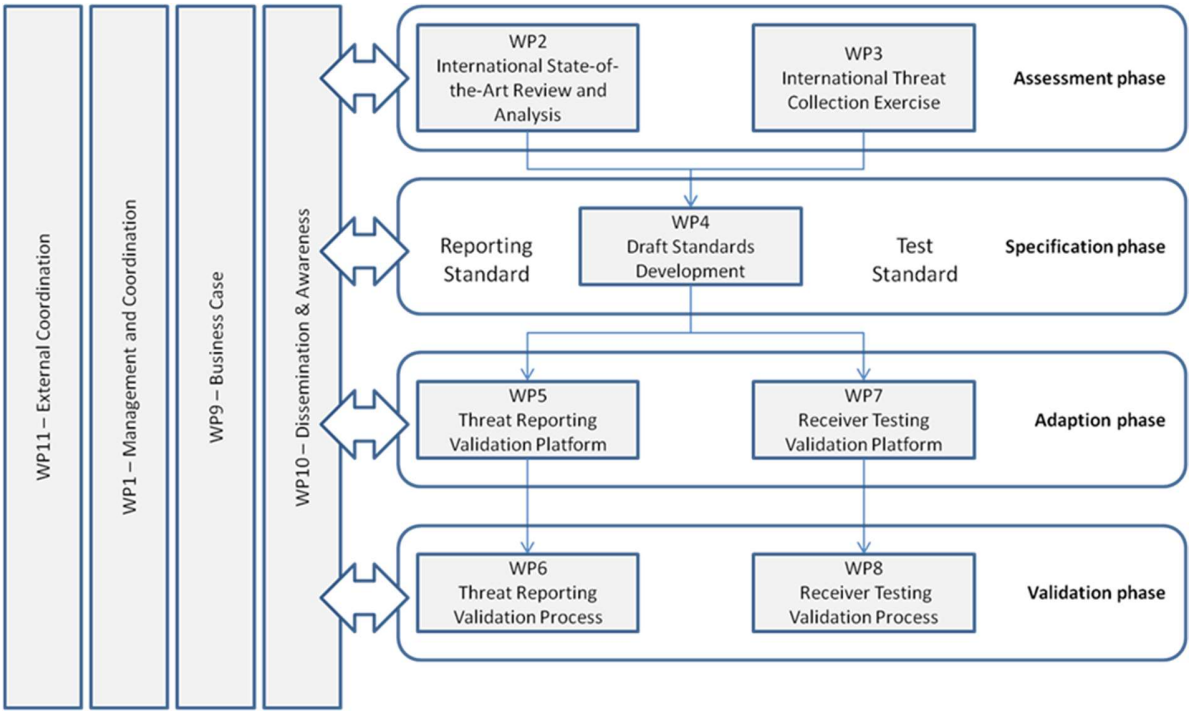


Figure 2-1: Overview of Approach

2.2 Objectives

The overall aim of the STRIKE3 project was to develop and validate new international standards for the monitoring, reporting and testing of GNSS threats. Within the STRIKE3 project, hardware was deployed in real world environments in order to monitor and report on real world threats that exist in the GNSS spectrum. Below are the eight overarching objectives that governed the project which were used to derive the programme of work (Table 2-1). Within the table below also lies the status of the objective including more details of in which work package the objective was met.

ID	Objective Description	Objective Complete?	Work completed to meet the objective
1	To analyze the international dimension concerning GNSS interference threats as well as identify specific regional challenges, programmes and initiatives which aim to seek solutions to the challenge presented by GNSS interference.	Yes	WP2 State of the Art Review
2	To carry out an International interference data collection campaign involving the deployment of sensors at international sites over a 3-month period to baseline the size and scale of the challenge.	Yes	WP3 International Threat Collection Exercise
3	To define and agree common minimum specifications for collecting, analyzing, reporting and exchanging GNSS threat information. This is seen as critical to the international efforts to tackle this problem.	Yes	WP4 Draft Standards Development
4	To adapt existing GNSS interference detection and reporting systems to comply with the minimum specification and to validate compliance through trials and experiments (including real world trials and open-air test site demonstrations)	Yes	WP5 Threat Reporting Validation Platforms & WP6 Threat Reporting Validation Process
5	To develop a GNSS threat testbench for evaluating GNSS receivers in the presence of the threats. This will involve subjecting existing GNSS receivers to the threats detected during the STRIKE3 monitoring campaign.	Yes	WP7 Receiver Testing Validation Platform & WP8 Receiver Testing Validation Process
6	To refine and strengthen the preliminary business case for GNSS threat detection, characterisation and testing.	Yes	WP9 Business Case
7	To provide support to the EU participation within UN International Committee on GNSS meetings. This is critical to promote Europe, STRIKE3 and the value of E-GNSS signals in delivering hardened GNSS solutions across all application domains.	Yes	Attended 2 UN ICG meetings to present STRIKE3

ID	Objective Description	Objective Complete?	Work completed to meet the objective
8	To promote the benefits and values of E-GNSS programmes within the context of protecting international applications of GNSS. E-GNSS offers more and better signals than existing GNSS. Access to new signals provides opportunities for enhanced mitigation techniques and opportunities to identify new differentiators and benefits of European signals.	Yes	Presentations at international conferences and attendance at meetings and workshops. Receiver testing results that show the benefits of Galileo signals.

Table 2-1: Summary of STRIKE3 Objectives

2.3 Milestones

The following table identifies the main milestones which were completed within the STRIKE3 project. The project commenced on 1st February 2016 and completed on 31st January 2019. The final review took place at the GSA in Prague on Wednesday 6th February.

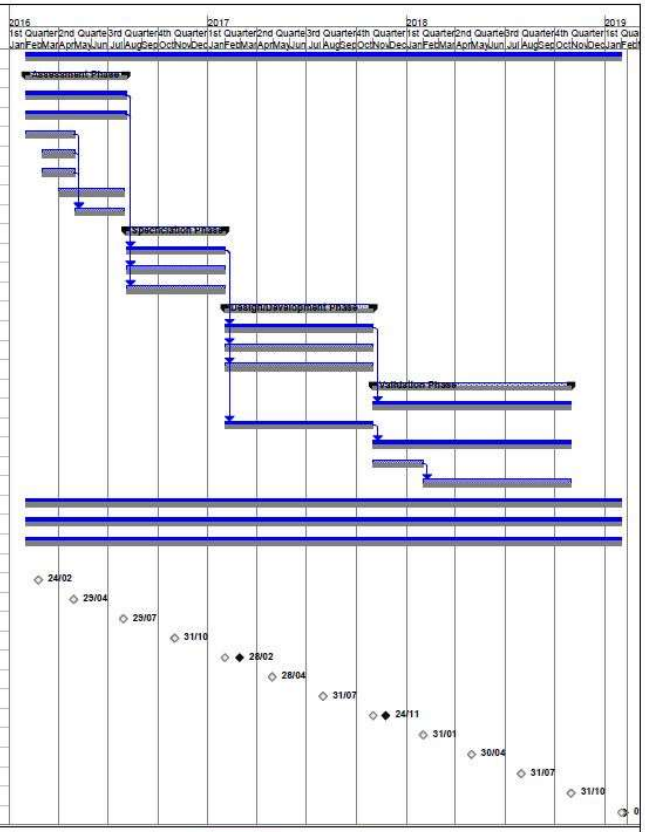
Milestone No.	Milestone Name	Relevant WPs	Date	Means of Verification and success criteria
M1	Kick Off	All	24 Feb 2016	Acceptance of project plan
M2	Requirements Baseline Review	3	27-28 Feb 2017	Review of requirements and draft STRIKE3 standards for threat reporting and receiver testing.
M3	Deployment Readiness Review (STRIKE3 reporting platform)	5,6,7,8	24 Nov 2017	Functional verification by test that the reporting platform and receiver testing platform function according to the draft standards.
M4	Final Review	All	6 Feb 2019	Completion and acceptance of all project deliverables

Table 2-2: STRIKE3 Milestones

2.4 Schedule

The figure below provides a high-level view of the schedule for the STRIKE3 project, as defined at project KO on in February 2016. The schedule has remained the same through the three years of the project and the project has been completed on time.

ID	WBS	Task Name	Duration	Start	Finish	Predecessors
1	WP1	Management and Coordination	783 days	01/02/2016	30/01/2019	
2	-	Assessment Phase	132 days	01/02/2016	02/08/2016	
3	WP2	International State-of-the-art Review and Analysis	132 days	01/02/2016	02/08/2016	
4	WP3	International Threat Collection Exercise	132 days	01/02/2016	02/08/2016	
5	WP3.1	Site Reconnaissance	65 days	01/02/2016	29/04/2016	
6	WP3.2	Equipment Deployment and Installation	44 days	01/03/2016	29/04/2016	
7	WP3.3	Configuration and Commissioning	44 days	01/03/2016	29/04/2016	
8	WP3.4	Operations and database population	86 days	01/04/2016	29/07/2016	
9	WP3.5	Analysis of results	65 days	02/05/2016	29/07/2016	7,6,5
10	-	Specification Phase	130 days	03/08/2016	31/01/2017	
11	WP4	Draft Standards Development	130 days	03/08/2016	31/01/2017	3,4
12	WP4.1	Draft Threat Monitoring and Reporting Standard	130 days	03/08/2016	31/01/2017	3,4
13	WP4.2	Draft Receiver Testing Standard	130 days	03/08/2016	31/01/2017	3,4
14	-	Design/Development Phase	195 days	01/02/2017	31/10/2017	
15	WP5	Threat Reporting Validation Platform	195 days	01/02/2017	31/10/2017	11
16	WP5.1	STRIKE3 Monitoring System	195 days	01/02/2017	31/10/2017	11
17	WP5.2	STRIKE3 Server and Database	195 days	01/02/2017	31/10/2017	11
18	-	Validation Phase	260 days	01/11/2017	30/10/2018	
19	WP6	Threat Reporting Validation Process	260 days	01/11/2017	30/10/2018	15
20	WP7	Receiver Testing Validation Platform	195 days	01/02/2017	31/10/2017	11
21	WP8	Receiver Testing Validation Process	260 days	01/11/2017	30/10/2018	20
22	WP8.1	Threat Selection	65 days	01/11/2017	30/01/2018	
23	WP8.2	Test plan and execution	195 days	31/01/2018	30/10/2018	22
24	WP9	Business Case	783 days	01/02/2016	30/01/2019	
25	WP10	Dissemination & Awareness	783 days	01/02/2016	30/01/2019	
26	WP11	Coordination	783 days	01/02/2016	30/01/2019	
27						
28	M1	KO Meeting	0 days	24/02/2016	24/02/2016	
29	-	Progress Review #1	0 days	29/04/2016	29/04/2016	
30	-	Progress Review #2	0 days	29/07/2016	29/07/2016	
31	-	Progress Review #3	0 days	31/10/2016	31/10/2016	
32	M2	Requirements Baseline Review / PR#4	0 days	28/02/2017	28/02/2017	
33	-	Progress Review #5	0 days	28/04/2017	28/04/2017	
34	-	Progress Review #6 / JRC data capture	0 days	31/07/2017	31/07/2017	
35	M3	Deployment Readiness Review / PR#7 / reporting trials (ARIC)	0 days	24/11/2017	24/11/2017	
36	-	Progress Review #8	0 days	31/01/2018	31/01/2018	
37	-	Progress Review #9 / receiver testing validation (JRC)	0 days	30/04/2018	30/04/2018	
38	-	Progress Review #10	0 days	31/07/2018	31/07/2018	
39	-	Progress Review #11	0 days	31/10/2018	31/10/2018	
40	M4	Final Review	0 days	06/02/2019	06/02/2019	



Project: schedule_at_KO
Date: 12/02/2019

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Baseline | Baseline Milestone | Baseline Summary | Progress | Deadline

Figure 2-2: STRIKE3 Project Schedule

2.5 Deliverables

Within the STRIKE3 project, the following list of deliverables were produced as outputs of the various work packages. Deliverables were produced for management, technical, business and exploitation activities.

Deliverable No	Deliverable Name	WP No	Dissemination Level
Management Deliverables			
D1.1	Project Plan (Management, Administrative, Financial)	1	CO
D1.2	Progress Report #1	1	CO
D1.3	Progress Report #2	1	CO
D1.4	Progress Report #3	1	CO
D1.5	Progress Report #4	1	CO
D1.6	Progress Report #5	1	CO
D1.7	Mid-Term Report	1	CO
D1.8	Progress Report #7	1	CO
D1.9	Progress Report #8	1	CO
D1.10	Progress Report #9	1	CO
D1.11	Progress Report #10	1	CO
D1.12	Progress Report #11	1	CO
D1.13	Final Project Report (internal)	1	CO
D1.14	Final Project Report (public)	1	PU
D1.15	Innovation Management Plan	1	CO
Technical Deliverables			
D2.1	International State of the Art Review and Analysis	2	CO
D3.1	International Threat Data Collection Report	3	CO
D4.1	Draft standards for threat monitoring and reporting	4	PU
D4.2	Draft standards for receiver testing against threats	4	PU
D5.1	Test Report on Compliance of Monitoring and Reporting Systems to STRIKE3 Standards	5	CO

Deliverable No	Deliverable Name	WP No	Dissemination Level
D6.1	STRIKE3 Validation Report - Part 1 (Threat Monitoring and Reporting)	6	CO
D6.2	STRIKE3 Threat Database Analysis Report	6	PU
D7.1	STRIKE3 Receiver Test Platform Design Document	7	CO
D8.1	STRIKE3 Validation Report - Part 2 (Receiver Test Platform)	8	CO
D8.2	STRIKE3 Receiver Testing Summary Report	8	PU
Business and Exploitation Deliverables			
D9.1	Business case	9	CO
D9.2	Business Plan	9	CO
D10.1	Dissemination Plan	10	PU
D10.2	Dissemination Report	10	PU
D11.1	External Coordination - STRIKE3 Animation	11	PU

Table 2-3: List of Deliverables from STRIKE3

Many of these deliverables are internal to the project, but those that are 'public', and are available more widely are highlighted.

2.6 STRIKE3 Project Partners

The members of the consortium were selected because of their complementary skills and demonstrable track records in the topic area. The team includes innovative developers of GNSS technology, specialists in GNSS interference algorithms and experts in testing and validation issues.

NSL

NSL as the coordinator of the consortium has managed the STRIKE3 project to success and enabled the installation of the DETECTOR interference monitoring probes around the world to form the international monitoring network.

FOI

FOI successfully led the validation testing for the STRIKE3 monitoring and reporting standards and supported the review tasks and standards development. Furthermore, FOI

provided their RF Oculus RF Monitoring system for use within the international monitoring network. FOI also hosted the Final Workshop in Linkoping, Sweden in which the receiver testing and results and analysis from the long-term monitoring were demonstrated.

NLS

NLS successfully led the state-of-the-art review and the receiver testing activities for the STRIKE3 project. NLS were also awarded several opportunities to publish in reputable GNSS publications which enabled the STRIKE3 project to gain awareness in the GNSS community.

AGIT

AGIT successfully led dissemination activities and supported the deployment and operation of several DETECTOR units within the STRIKE3 project. AGIT also organised the first STRIKE3 workshop at ARIC in Germany in which a number of live demonstrations took place to show the capabilities of the monitoring equipment.

GNSS Labs

GNSS Labs supported activities within the state-of-the-art review, standards development and deployment of the STRIKE3 detection equipment.

ETRI

Within the STRIKE3 project, ETRI supported the development of the standards, developed a testing platform adhering to the recommended approach within the test standards documentation and validated the test standards by carrying out end to end testing on GNSS receivers.

3 Main Project Outputs/Findings

The STRIKE3 project delivered four main outputs, as described below.

3.1 Draft Standards Documentation

Within the STRIKE3 project, two draft standard documents were created. This includes a document on threat monitoring and reporting and a document on receiver testing against threats. As the main legacy of the STRIKE3 project, the documentation created within the STRIKE3 project validates methodologies for threat monitoring and reporting including details of test architectures, performance metrics, criteria and procedure for selecting threats and the application of the proposed standards. The two documents (D4.1 and D4.2) are publicly available on the STRIKE3 website (http://www.gnss-strike3.eu/). It is noted that these documents cannot be classified as formal standard documentation at the moment as they are not currently accredited by a standardisation body, but should instead be treated as proposed methodologies for future monitoring or testing activities by interested stakeholders.

3.2 Receiver Testing Activities

Within the STRIKE3 project, automated testing was carried out with a variety of receivers against a variety of real-world threats. This was partly to enable the validation of the proposed test standards, and also to gain an understanding of the resilience of current receivers (of different types) to real-world threats. The results are available in the STRIKE3 Receiver testing summary report (D8.2). One of the interesting results of these tests is that the Galileo signal E12 signal shows some increased resilience compared to GPS L1 (for some interference types).

3.3 International Threat Monitoring Network

Within the STRIKE3 project, an international monitoring network has been deployed worldwide containing more than 50 sites. The number of sites and the diversity of the international locations were well beyond initial expectations of the project. Furthermore, through the development and installation of this network an interested community has been created, and the generation of the results has provided that community with awareness of the issue and evidence of potential threats to their infrastructure. This in some cases has allowed authorities to put further measures in place (further monitoring, enforcement and education). A summary of the monitoring results (suitably anonymised) is shown in the STRIKE3 threat database analysis report (D6.2).

In addition to the results and analysis, an extensive database of hundreds of thousands of events covering all types of signal (intentional and unintentional) has been populated. This database as an output of the project has potential for future use, for example in Jammer tracking applications, further receiver testing against threats and the development of mitigation techniques.

3.4 Dissemination Activities

The STRIKE3 project successfully completed various dissemination activities over the three years of the project, this has included two successful workshops, attendance in multiple conferences all over the globe and invites to many events. Overall, STRIKE3 has been presented at/in the following:

- 33 conferences/workshops all over Europe, USA, Asia and Australia
- 11 papers created for various conferences
- 8 publications in scientific journals and magazines
- 5 articles about STRIKE3 in various magazines, newsletters and online.

Within the STRIKE3 project, several pieces of dissemination material have also been created such as quarterly reports showing some anonymised results from sites, an animation on the STRIKE3 project for conferences and workshops, a project website and various posters.

3.4.1 STRIKE3 Workshops

The first stakeholder workshop within the STRIKE3 project took place at AGIT in Germany on the 2nd and 3rd November 2017. As part of the workshop an on-site live jammer demonstration took place. Twenty-two stakeholders participated in the workshop from the GSA, European Commission, ESA, and various Regulation Authorities from all over Europe. As part of the workshop, information was presented regarding the project status, presentations on STRIKE3 monitoring activities, an introduction to standardization on Reporting & Testing and qualified feedback from stakeholders to the project team on the results of monitoring stations results and their own experiences with interference.

The 2nd stakeholder workshop took place at FOI in Sweden on 11th and 12th December 2018. Overall 28 stakeholders participated from the GSA, aviation authorities, frequency regulators and various other authorities from Europe and beyond. For the workshop, a presentation was provided on long term monitoring results and analysis that had been completed, feedback was received from user experiences from the monitoring and a review of the standardization of reporting and standardized receiver testing documents was provided. Live demonstration of the receiver testing set-up and impact of the jamming signals on different receiver types was also provided.

3.4.2 Project Website & Publications

For STRIKE3, a project website was designed and created by project partner AGIT (http://www.gnss-strike3.eu/). The website was made available in July 2016 and included an introduction to the project, explanations of the main goals and a downloads section of project documentation. Furthermore, various publications publicized the STRIKE3 project. This included:

- VDI-Wissensforum, Sept. 2018 (German Text): “Internationale Langzeitanalysen von GPS-Störungen und Empfängertests”

- Inside GNSS, July-August 2018: “How can we ensure GNSS receivers are robust to real-world interference threats?”
- GPS Solution, 2 August 2018, “A New Implementation of Narrowband Interference Detection, Characterization and Mitigation Technique for a Software-defined multi-GNSS Receiver”
- The Journal of Navigation, Oct. 2017: “GNSS Threat Monitoring and Reporting: Past, Present, and a Proposed Future”
- GPS World, May 2017: GPS World reported about STRIKE3 being presented at European Navigation Conference, Switzerland.

4 Conclusions

Within the international STRIKE3 monitoring network, more than 50 sites have been set up over 20 different countries. This network has allowed the STRIKE3 project to make comparisons based on infrastructure, time of day, the number of events over a period of time, events with the highest power and many other variables. The international network as a result, has allowed site owners to understand their RF environment better and understand any threats that may be present in their area. This has then enabled the site owner to think about any mitigation that may be needed and how they will conduct themselves in the future. At many STRIKE3 sites, monitoring is continuing beyond the end of the project, meaning more data is being gathered and provided to sites for their information. The more information that is gathered by the network, the better picture the site can get on their environment.

The database created within the STRIKE3 project has become an extensive catalogue of threat signatures. This has allowed analysis into whether the threats collected are intentional, unintentional, have an impact on the receiver or not, whether new threats have appeared, whether new patterns have begun to show and many more. In terms of the future use of the database, as several sites still have their monitoring units running, the database remains a resource for data collection and analysis. Moreover, in the future, the database provides a potential resource for further analysis for example for the types of signals, impacts and investigation into common signals at sites.

Within the database a large variety of different threats have been collected. Through the collection of these threats we have been able to understand RF environments better and understand the types of threat that affect infrastructure that we rely on. Within the project some analysis has been completed to compare the threats and aid futures investigations in the causes of these threats, however as the monitoring network remains, further analysis can be completed to build up a better picture of the issues that are present and how they can start to be mitigated in the future.

With regards to the future of the main project deliverables created within the project, the draft standard document on threat reporting provides a methodology for threat monitoring reporting. This document is available on the project website for future use by any interested parties. Moreover, the methodologies within the document will also be taken forward in any other future monitoring activities that may take place. In addition, the receiver testing draft standard document provides a methodology for receiver testing against real world threats. This document is also available publicly on the STRIKE3 website and can be taken forward as a methodology for testing activities for example to help develop and test improved interference mitigation techniques.

During the three years of the STRIKE3 project, a large variety of dissemination activities have taken place which have allowed the STRIKE3 project to be publicised in many locations all over the world. Furthermore, due to the presentations and papers that have

been created during/for the attendance of conferences and events, connections have been made that have resulted in the purchase of monitoring units. This has meant that a larger network has been created as a result and in terms of future activities these sites enable future monitoring and system enhancement.

During the project, we have worked with many stakeholders from all sectors to establish the monitoring network. Therefore because of the network, different communities and have become better informed of threats that may affect them which has ultimately helped guide future activities in monitoring and threat mitigation.

Moreover, with regards to knowledge exploitation, the STRIKE3 project has enabled one patent the method of testing a PNT configuration, has enabled the creation of 3 products, 2 prototype developments and several business opportunities in testing services, additional contracts and product sales.

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