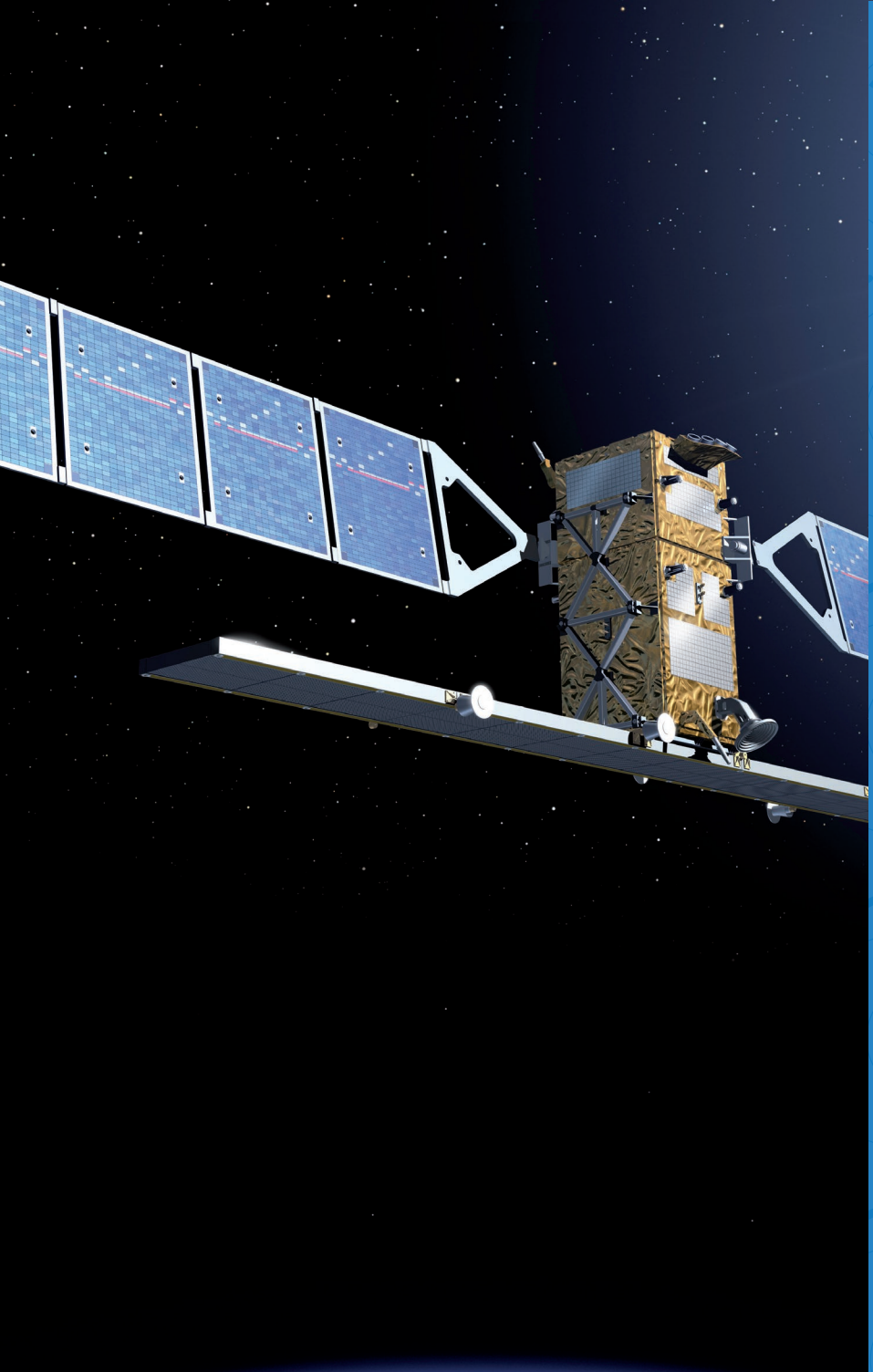


UK SPACE AGENCY

EASOS
EARTH AND SEA
OBSERVATION SYSTEM

World-leading management information and decision support platform to monitor and manage environmental and human challenges.

CATAPULT
Satellite Applications

Project overview

Each year, the combined impact of marine oil pollution, deforestation and flooding on the Malaysian economy amounts to several billions of dollars. The Malaysian government and UKSA identified these as three development challenges that might be addressed through innovative satellite-based solutions. These solutions were developed through the Earth and Sea Observation System *(EASOS)* project, funded via UKSA's International Partnership Programme.

The aims of the EASOS project were set out in the original calls for proposals issued by UKSA and mandated by the government of Malaysia.

Project Aims

"To provide informed and coordinated decision-making capability to 23 Government Agencies in Malaysia through a user centred dashboard delivering information and analysis on three environmental challenges.

By providing this decision support solution the Malaysian team will be able to undertake a business change / business implementation to:

- Reduce the amount of degradation to the mangrove coastline in Malaysia by reducing marine pollution in the Malacca Straits. This will protect habitats, prevent coastal erosion and improve aquaculture.
- Reduce the social and environmental impact of illegal logging and to increase the economic benefit from legal logging for Malaysia.
- Reduce the economic and social cost of flood events."

The objectives of the EASOS project were also set out in the original calls for proposals issued by UKSA and mandated by the government of Malaysia. These were:

"To reduce marine pollution by providing in-situ and remotely sensed data to an integrated dashboard for two sectors of the Malacca Straits to support identification of marine pollution events and the vessels illegally dumping bilge water. Increased detection and subsequent publicity should lead to a reduction in events. In addition, provide data to local agencies to enable them to stop oil slicks reaching land.

- To reduce illegal logging by providing in-situ and remotely sensed data to an integrated dashboard thereby identifying incidents of illegal logging which are greater than 50 sq. metres in two regions of Malaysia. This will enable the interception of those involved in illegal logging, which as awareness increases should lead to a reduction in illegal logging, benefiting those communities affected. Through the implementation of an asset monitoring system the project will support the legal licensing of the forestry industry which should derive increased tax revenue and improve local economies through legal logging.
- To implement a flood warning system in two catchment areas in Malaysia based on probability of short-term risk to increase the time available to prepare for incidents. The system will be based on modelled risk exposure maps which will be available through the common dashboard to assist with flood event and infrastructure planning."

Project approach and achievements

A stakeholder group of 23 government agencies was formed in Malaysia and in the UK the Catapult brought together a consortium of 10 UK companies each with specialisms to address each of the thematic areas. This created a live decision-support platform that fuses terrestrial and satellite data to help tackle these global environmental challenges which impact Malaysia.

The EASOS project developed three innovative tools, Flood Watch, Marine Watch, and Forest Watch which make use of frequent-periodic satellite data to detect, monitor and produce rapid early-warning alerts respectively for flooding, marine pollution and deforestation. One of the advantages of satellite-based Earth Observation *(EO)* is the ability to monitor large surface areas quickly, frequently and cheaply.

EASOS' space-based solution provided more accurate and more frequently - updated information on important environmental parameters than would have been possible using a ground-based alternative and has been shown to be more cost effective than drone-based aerial surveillance for the same purpose. Satellite aspects included ESA's Sentinel 1 and 2 EO data combining radar and visual imagery, access to additional high-resolution imagery on request through a data hub, the acquisition and analysis of Synthetic Aperture Radar *(SAR)* data for oil spill detection and use of Automatic Identification System *(AIS)* data for correlating locations of surface oil with movements of vessels.

During the project, each of the tools were developed, tested and piloted in a specific Area of Interest identified by the Malaysian authorities, which served as a pilot/testing area for services that can be rolled out throughout the country or adapted for other locations as required.

The tools are intended to synthesise complex information to provide prompt and accurate decision support and so improve the capabilities of Malaysian agencies to respond in an appropriate and timely manner to risk events and so minimise the environmental, social and economic impacts of seasonal flooding, marine oil pollution and illegal logging.

By seeking to improve the lives of the people of Malaysia in this way, these objectives aligned with the SDG goals 13 *(13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters)*, 14 *(14.1 By 2025, prevent and significantly reduce marine pollution of all kinds)* and 15 *(15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.)*

The three challenges addressed by EASOS in Malaysia

Flood Watch

The problem:

In 2014 the worst monsoon flood to hit the East Coast of Malaysia in three decades triggered major flooding across the country resulting in 21 deaths and 250,000 people displaced from their homes. As well as the environmental and human costs, the economic loss and financial burden on the government was enormous with floodwater damaging key infrastructure including banks and significantly slowing down consumer spending across the three states worse affected. Monsoon floods are not a new phenomenon in Malaysia, and without an effective early warning system, protecting affected populations and infrastructure remains a challenge for the agencies responsible for flood response.

The solution: Floodwatch

Multiple data sets are combined to generate early warning alerts that enable response teams prepare, activate evacuation plans where necessary and deploy flood defences in a timely manner. Use of the service would provide improved advanced warning times, more time to develop targeted responses, better information about impacted areas and more accurate prediction of improvement/worsening of conditions. Ultimately, action by the Malaysian flood response agencies, informed by the EASOS early warnings, would result in a reduction in the numbers of fatalities, and a reduction in damage to personal property, businesses and infrastructure attributable to flood events.

EASOS Flood Watch focused on three Areas of Interest three river catchments: Perak, Kelantan and Kemaman, and provides:

Flood Forecasting

- Flood forecasting up to 7 days in advance allowing contingency planning
- Detailed mapping of areas at risk of flooding updated every 6 hours as new information is received
- Ability to predict areas of flooding risk at 100M resolution or better
- Integration to allow ordering of relevant satellite imagery
- Understanding of the financial and human impact of flooding

Advanced Decision Making:

- Advanced decision support
- Continuously *(24/7)* monitor river and rain gauge state to allow real-time monitoring of flood development
- Forecast the impact of rain
- Conduct impact mapping and analysis prior to an event
- Users receive alerts tailored to their specific needs
- Identify specific impacts to infrastructure such as road networks and bridges
- Identify suitable escape routes and safe havens
- Receive information on the likely start, duration and intensity of flooding
- Visualise flood predictions in a simple user interface to support rapid decision making
- Identify areas of high statistical likelihood of flood for planning, analysis and mitigation management

Flood Hazard and Risk Modelling

- Hazard Maps provide static analysis maps showing 1 in 5, 20, 100, 1,000 and 10,000-year scenarios for each flood mechanism. These maps are used to interpret potential flood extents and depths across each region allowing a range of scenarios to be visualised by increasing or decreasing the severity of the event
- Exposure Maps show the relative exposure based on the population living in each area to better understand the impact of predicted flooding.
- Risk Maps show the total population at risk of flooding by single or multiple flood mechanisms. This allows analysis of the relative flood risk considering probability and the impact on the population

Marine Pollution

Marine Watch

The problem:

As one of the busiest and most important trade routes in the world, the Straits of Malacca are the main shipping channel between the Indian and Pacific Oceans: a ship sails through the Straits on average every 3.6 minutes, navigating through the shallow, narrow channels. The coastline of the Malacca Straits is home to many species of birds and mangrove dwellers like crabs, beady-eyed mudskippers and crab-eating macaques. In recent years, the number of ships using the Straits has been increasing, coinciding with a rise in marine pollution rates as vessels discharged the contents of their bilge tanks including large quantities of oil, sewage and other toxic contaminants. Cleaning of bilge tanks represents up to 10% of the operational costs of the ship, therefore there is a significant incentive to undertake illegal dumping. The impacts of this pollution to the Malaysian coastline are significant affecting wildlife and coastal mangroves, and impacting local industries such as fishing, agriculture and tourism as well as harbours and energy infrastructure.

The solution: Marinewatch

An automated visualisation tool that would enable the Malaysian authorities to:

- Identify and locate potential oil slicks on the surface of the ocean
- Forecast the dispersal of the slicks over the coming 84 hours to pinpoint threatened areas of shoreline or infrastructure
- Trace the movement of the slick backwords through time to identify the likely place of origin
- Identify vessels in the area and their movements, to home in on those responsible for the pollution

Firm action by the Malaysian authorities, based on the intelligence provided by EASOS, would have an immediate and sustainable knock-on effect on the operators and owners of all vessels passing through the Malacca Strait - leading to a significant drop in the number of vessels discharging bilge in that area.

Early identification of oil spills and their trajectories would allow efficient deployment of coastal protection and oil disbursal assets, thus protecting the vulnerable coastline from environmental damage and reducing the economic costs of clean-up operations.

A reduction in bilge discharges and early detection of slicks was also expected to have a positive impact on food sustainability and increased revenues for fishermen and farmers, although these impacts were not open to measurement or direct attribution to the project.

EASOS Marine Watch focused on Peninsula Malaysia exclusive economic zone (below 5 degrees latitude) and provides:

- Detection of potential oil pollution incidents on the surface of the ocean
  - Radar satellite imagery is used to automatically detect potential oil spills and alert the relevant authorities to their presence. EASOS automatically acquires the data it needs. EASOS utilises open-source satellite imagery
- Forecasting of marine oil pollution dispersal for the next 84 hours
  - Early warning of where oil spills may reach land. Modelling techniques for forecasting the likely dispersion of a spill based on environmental data regarding the sea state, bathymetry and meteorological conditions, as well as the oil type and its estimated volume. Users can see the predicted location of the spill at 30-minute intervals over the 84 hours from the satellite image being captured. The application can also predict where and when oil will hit land and then highlights its estimated concentration. The application also integrates important ecological information highlighting sensitive sites such as mangroves
- Automatic alerts based on areas of interest, oil detection size and forecasted coastal impact
- Identification of candidate vessels that could be responsible for slicks
  - The application allows users to model a detected slick up to 84 hours backwards in time to indicate from where and when the spill may have originated. The application uses vessel tracking (*Automatic Identification System (AIS)*) data to detect, track, and help identify ships in the monitored areas and allows comparison of vessel locations with oil spills
- Modelling of what-if scenarios for oil spills and the impact of boom deployment

Illegal Logging

Forestwatch

The problem:

Illegal logging affects the Malaysian economy, its indigenous communities and biodiversity, and a number of important endangered species. It is indirectly responsible for a reduction in legal employment, a loss of legitimate commercial revenue and a reduction in taxable income. With such a large area of land, it is difficult to identify locations where unauthorised, illegal logging is taking place.

The solution: Forestwatch

Combining multiple data sources including satellite imagery to identify locations where forest cover was being reduced and track the rate of forest cover change, and issue alerts to enable the Malaysian government to identify and respond to unauthorised removal of forest cover at an early stage in order to combat illegal deforestation and forest degradation. In turn, this would help to ensure the preservation of the forest estate while offering protection to indigenous population and wildlife.

EASOS Forest Watch focused on two regional AOIs in the state of Terengganu and provides:

- Regional level detection and monitoring of logging activities
  - Provides users with the ability to monitor changes within a forest area; from regional to country scale on a monthly basis. Changes in forest cover exceeding 0.02 hectares are detected and alerted to the users. EASOS helps users to detect general illegal logging, encroachment of agriculture and inappropriate extension of logging concessions into protected environments
- Enforcement of forestry legislation and management practices and supports authorities to protect the endangered species threatened by their diminishing habitat
  - EASOS Forest Watch uses satellite imagery to automatically monitor vast swathes of forest for protection purposes - it detects changes to the forest canopy and automatically notifies users

Project partners

The EASOS consortium was made up of a group of diverse organisations led by Satellite Applications Catapult, a global leader in the innovative applications of earth observation technology and the project's primary grantee, prime consortium lead and UK Project Management Office. The implementation partners who contributed to developing the EASOS services were:

Flood Domain

- **Ambiental** - Domain lead for developing a modelling platform with real-time interface for flood forecasting *(hazard, risk, and exposure)*, including maps used to interpret potential flood extent and flood depths across each region.
- **EOSphere** – Responsible for the installation of system at the UK data centre and the Malaysian Space Agency *(ANGKASA)* to provide data from the Himawari geostationary satellite, *(operated by the Japanese meteorological agency)* to supplement high-resolution data from the European Space Agency's Sentinel 1 and 2 satellites.
- **Oxford University** - Responsible to research different machine learning/probabilistic approaches to improve the tools developed within each of the project domains (*though mainly focused on Marine Pollution and Flooding)*. Provided training to Malaysian stakeholders in machine learning/probabilistic approaches.

Marine Domain

- **Plymouth Marine Laboratory** - Domain lead for developing an oil slick detection tool using Sentinel-1 data as well as a modelling platform and input data and user-interfaces for use of the tool in two sectors of the Malacca Straits.
- **RiskAware** - Modelled the dispersion of detected oil spill from source location and its potential impact on the coastline, including projected impacts of booms use to mitigate dispersion. Riskaware also provided capability to assess potential sources of the spill and possible offending vessel information using automatic identification shipping information
- **AutoNaut LTD** – Responsible for building the robotic sea-surface vessels – the AutoNaut - to enable collection of data/information on oil-spill events for ground-truth and validation of sightings from satellite sources and transmit to interested users.

Forest Domain

- **Telespazio Vega** - Domain lead focused on the development and demonstration of a deforestation monitoring service for Malaysia. Showcasing the effectiveness of different satellite data sources including Cosmo SkyMed and Sentinel data.
- **Leicester University** - Obtained optical change-detection information on forest cover loss and determined consequences for ecosystem service provision.
- **Earth Observation** - Developed capability to geo-reference locations of supply chain transitions to allow linkages between legal logging sites and routes and the mapping of logging activity and transport routes as identified in the domain services.

In Malaysia, a total of 23 Governmental agencies formed the initial stakeholder group which were assembled by the National Defence University of Malaysia. During the period of implementation a number of changes occurred in the institutional landscape, most significantly a change of government following a general election in 2018, which saw ministries restructured and the merging of the Malaysian Space Agency *(ANGKASA)* with the Malaysian Remote Sensing Agency to create a new Malaysian Space Agency *(MYSA).*

It became clear during the course of the project that a smaller core of institutional stakeholders were key to the project's success, and that the natural home for the EASOS capabilities was in the Ministry for Natural Resources and the Environment *(later renamed the Ministry of Water, Land and Natural Resources)* which is home to all the relevant governmental agencies including Forestry, Marine, Drainage and the mapping agency, JUPEM.

Since the completion of the project, regional authorities in Sabah and Sarawak (*the two states that make up the Malaysian part of the island of Borneo)* have started to take an active interest in the EASOS services.

Solution Development: a User Centred Design approach

The project used a User Centred Design approach from the start and engaged with the key in-country partner agencies to understand the existing working practices and technology, identify their needs and expectations of the proposed services.

The solutions were developed through an iterative process, through four 'release' stages each building in capability and complexity on feedback received from testing of the previous phase by the partners. Each stage culminated with the provision of training and support materials to best ensure the new capabilities were understood and able to be used. Release four – the fully developed automated service – went live during the final phases of the project and has been operational ever since.

The EASOS technical solution provides a single technology platform that understands the Malaysian physical terrain and coastline, gathers the required data from disparate sources; satellite data, static sensor data, current conditions data *(weather, tide etc.)*, combines all this information and then undertakes timely modelling to address the end-user needs i.e. predict flooding, identify oil pollution and detect deforestation. The outputs of the modelling *(and other contextual information)* is presented to users in a secure and simple to understand web interface. The innovation delivered by the EASOS solution was the aggregation of four key elements:

1. The merging of multiple disparate data sources

2. The modelling functionality

3. The timely delivery of the modelling outputs

4. The User Interface design to present complicated information in a simple format

Adaptive management

Through the application of agile project management and an iterative process of solution design and user testing, the EASOS solution was successfully developed for all three domains and has been running non-stop since early 2018. Data is ingested into the platform from Satellite and in country sensor data and fused with base data for the Areas of Interest in Malaysia. The EASOS consortium partner algorithms are then applied to produce the decision support intelligence.

These products are made available 24/7 on secure and resilient web applications. The services include automated alerts issued to Malaysian authorities whenever a user-specified threshold was exceeded. Thus, for example, the marine authority is able to set their own parameters for the size and location of detected oil spills, in order to trigger an alert.

The applications have been demonstrated to the EASOS in-country stakeholders and users have been trained in their use.

During the project implementation period, a number of course corrections were implemented, in order to maintain relevance and effectiveness of the solutions. Among these, the following important issues and responses demonstrate adaptive management in practice:

- During implementation the level of buy-in to the project concept from many of the 23 listed Malaysian beneficiary agencies was found to be lower than had been anticipated at the time of UKSA issuing the call for proposals: the number of closely collaborating agencies was therefore reduced to those likely to be the primary end users and most direct beneficiaries of the solution. Considerable effort was made to raise their awareness of the potential of the solution to improve their operational capabilities, through demonstrations, testing of prototype and early-release version of the tools, collaborative response monitoring exercises and provision of pro-bono support during live responses to emergencies.

- During implementation it was also found that the initially requested Integrated Dashboard was not a requirement of the Malaysian agencies, and so this aspect was dropped in consultation with the primary end user organisations.

- The project implementation team had to navigate complex changes in the Malaysian policy context due to a change of government following the general elections in 2018. This presented potentially grave risks to the project's relevance and sustainability, which were mitigated to some extent by the granting by UKSA of a six month extension to the original 18 month project duration, and subsequently by the continuation of sustainability work under additional funding that was committed by the Catapult from its own resources.

Sustainability model

From the start, the sustainability model for EASOS was based on securing an ongoing procurement/user licencing arrangement from the Malaysian Government for access to the online decision support tools and alert service. The preferred route was to provide this as 'Software as a Service' *(SAAS)*, which allows for continued improvements and updating of capability by the service provider, rather than selling a static software package as such.

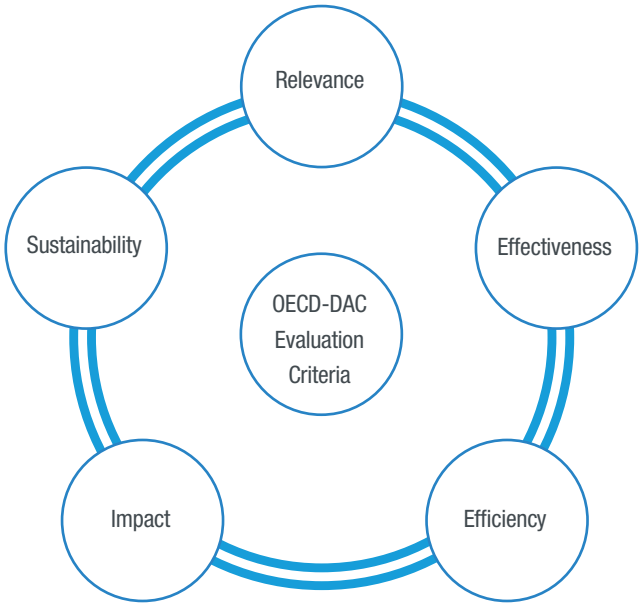
As part of the SAAS offering, government agencies have access to the visualisation tools and receive tailored alerts of flood, oil spill and/or deforestation events, generated by the system.

At the same time, the services and systems developed under the EASOS project have a relevance and potential application in other countries and for other sectors, and so the business plan also includes ambitions for expansion and scale-up. A number of countries are being considered for the next phase across Asia and Latin America, while EASOS has the potential to address a wide range of environmental management challenges, not limited to the three original domains that were identified by the Malaysian government.

Promotion in Malaysia is ongoing via a non-governmental agency, KASI, which showcases and demonstrates capabilities and handles negotiations with potential government clients. During the period immediately after the end of the IPP funded project, Catapult has made a strategic investment of its own resources into continuing the services and so alerts continue to be issued on a pro bono basis, in order to enable interested end users to assess the value added compared to their existing capability, during live operations.

A commercial model has been developed to support the expansion of EASOS into other countries and other services. The model is one of exploiting the EASOS 'brand' as an umbrella under which UK satellite-based services in the areas of sustainable development and disaster resilience can achieve greater market profile and access. Interested government agencies and other potential clients would have access to the service under a commercial agreement, which would cover the costs of tailoring EASOS services to their specific context and user needs and allow for different levels of service access depending on the user requirement and budget.

Monitoring and evaluation



- The project's M&E plan established a rigorous framework for measuring and assessing the project's results, based on the project's intervention logic (Theory of Change).
- A series of independent external evaluations were scheduled to assess the process, impact and economic (cost-effectiveness) aspects of the project, using a mixed methods and theory-based approach to draw conclusions and recommendations under each of the OECD-DAC's criteria for evaluation of aid funded projects: Relevance, Efficiency, Effectiveness, Sustainability and Impact.
- An initial evaluation was conducted at the end of the project's IPP-funded phase and applied process and economic evaluation approaches to assess the project's performance and likely cost-effectiveness of the solutions. Following the closure of the IPP funded project phase, a first legacy evaluation was completed during 2020, and a final legacy evaluation is scheduled for the second part of 2021.

Independent evaluation - findings

The external evaluation team noted challenges to implementation that resulted from weaknesses in early stage scoping and stakeholder engagement that were overcome via active and adaptive management approaches and the adoption of Agile project management methods.

The tools developed were judged to be highly innovative, and both relevant and effective to counter the threats to Malaysia in each of the three domains. While levels of government agencies' engagement across the three applications were seen to vary, promising signs of potential impact and longer-term sustainability were detected.

An initial Cost Effectiveness Analysis showed the EASOS solutions to be more cost effective than other possible ways of monitoring and supporting responses to the same hazards.

Independent evaluation - lessons learned and conclusions

The main lessons learned from the two evaluation studies conducted to date can be summarised as:

- **Project Scoping and engagement in-country:** EASOS was the first *(possibly the only)* IPP project to be initiated as a "tactical call" in which a developing country's Government agencies agreed with UKSA a set of requirements which were then opened to tender to UK companies. During implementation it emerged that the expectations of the Malaysian and UK partners were not fully aligned. Similar projects should include an inception/pilot phase in order to develop a thorough understanding of the context, verify all aspects of the project's intervention logic and secure mutual understanding and partner buy-in to the process before proceeding to implementation. Working closely with in-country partners and end-users throughout increases the chances of the technologies being used and having impact.

- **Timescale:** It was recognised at the start that IPP EASOS has a very aggressive timeframe, which allowed no scope to deal with unexpected delays or changes to the project context. A longer timeframe would have enabled the project to both demonstrate the system's value and adapt to changes to policy and institutional context more fully before the end of IPP funding.

- **Sustainability strategy:** EASOS sustainability aspects were developed as the project progressed. Greater clarity on sustainability routes could have been gained with an earlier and longer term in-country engagement. Successful customer use cases in Malaysia provide the key to securing scale up opportunities elsewhere.

- **IPP as a development programme as well as a technology innovation programme:** UK businesses participating in the EASOS project need to have their strategic business interests closely aligned to the goals of the project, including both the SDG goals and secondary benefits through building the UK Space Sector. This will avoid a risk that participants seeking IPP funding to develop interesting novel technologies but that are neither ultimately used nor impact the SDGs.

- **Added value of research organisations for technological knowledge and spill-overs:** Research organisations can strengthen the value-offering of the services and products through their deep technical knowledge. Other business consortium partners can also learn and gain skills from interacting with the research partners. They also play a key role in distributing technical knowledge to other enterprises and sectors.

Implementation of EASOS has provided the Catapult and its partners, including UKSA, with a valuable learning opportunity. All have emerged with a far more nuanced appreciation of the challenges and opportunities of developing innovative solutions to overseas development challenges, as well as growing expertise in how to deliver value in this important market space.

The technological ambitions of the programme, as set out in the proposal, were met in full. The system that was designed and operationalised is powerful, innovative and offers a blueprint for expansion and growth through:

- A generic set of data ingestion services that meet the needs of all three applications and can be extended to include additional data sets

- A data management and organisation structure that is robust, extensible and secure

- A framework for algorithm operation that allows specific datasets to be provided, analysed and results created in a modular form allowing additional multiple algorithms to be inserted

- A series of visualisations tools that can extend to include additional layers, background mapping, analysis and decision support

- A recognised market presence and brand identity that unites service offerings across different domains

When combined these elements offer a rapid and effective route to the creation of additional services reaching a far wider range of markets, challenges and valuable outcomes. The EASOS brand provides an ideal opportunity to consider and develop additional services and their associated applications to tackle development challenges in a range of other sectors.

Impact case studies

Although the evaluation did not set out to measure impacts, the project was able to deliver some notable examples of early impacts even before the end of the IPP funding phase. These case studies demonstrate how the EASOS services might deliver significant benefits in the future, when deployed on a larger scale, and are described here:

1. **Putri Sea, June 2017**

   On 15 June 2017, an explosion on the Merchant Tanker *(MT)* Putri Sea oil tanker, in a busy shipping lane off the southern state of Johor close to the Malaysian-Singapore border at Pengerang was reported by the Singapore Police Coast Guard to the Malaysian Maritime Enforcement Agency *(MMEA)*. The tanker, registered in Malabo, Equatorial Guinea, was carrying crude oil when it sank with the loss of all six of its crew. Approximately 40,000 barrels of crude oil were released into the water, creating a 3km wide slick off the coast close to a major oil refinery and petrochemicals integrated development project in Pengerang. Aware of the serious threat due to the spill's proximity to the region's coastline, the Malaysian authorities contacted the EASOS team to seek support. This incident was particularly sensitive because it occurred in proximity to the Singapore coastline.

   The key requirement was modelling the likely trajectory and dispersion of the oil slick, as it moved along the Straits. The EASOS UK Marine Watch team prepared satellite images and oil trajectory modelling to understand and predict the impact of the spill on the coast of Pengerang and Singapore.

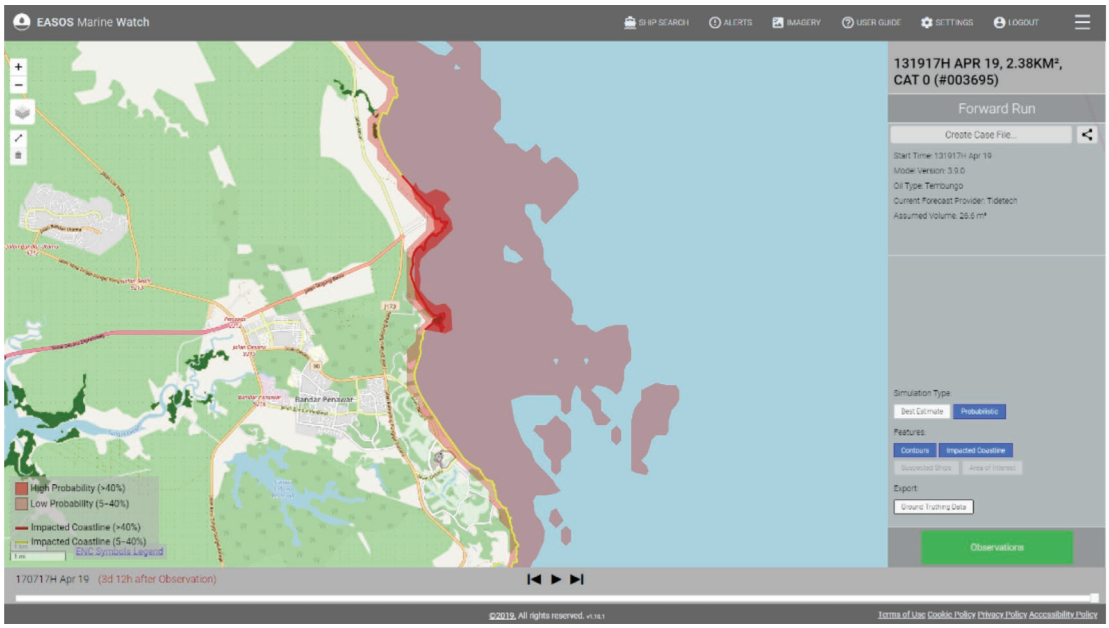
   The trajectory modelling provided by EASOS assisted the Marine Department in their operation especially in coordinating the deployment of a 2.4 Km oil boom and five oil dispersal craft to protect the Pengerang terminal and port as well as a recreational beach and housing area to the east of Pengerang. This effort was supported by Pengerang port authorities, which also deployed oil dispersal assets. Separately, the Singapore Maritime and Port Authority deployed three oil dispersal craft to prevent oil landing to the East of Changi.

   Mr Mohd Fairoz bin Rozali, Principal Assistant Director of the Marine Department Malaysia confirmed that the combination of real-time satellite data and imagery, and 72 hours dispersion modelling of the spill's trajectory, correctly predicted the movement of the slick towards the Dialogue Pengerang oil complex with the modelling proving to be over 90% accurate. The accuracy of the model enabled prompt, effective action to be taken to contain the oil spill and so prevented any oil making landfall at the coast either in Singapore or at Pengerang.

2. **Johor coastline oil spills, April-May 2019**

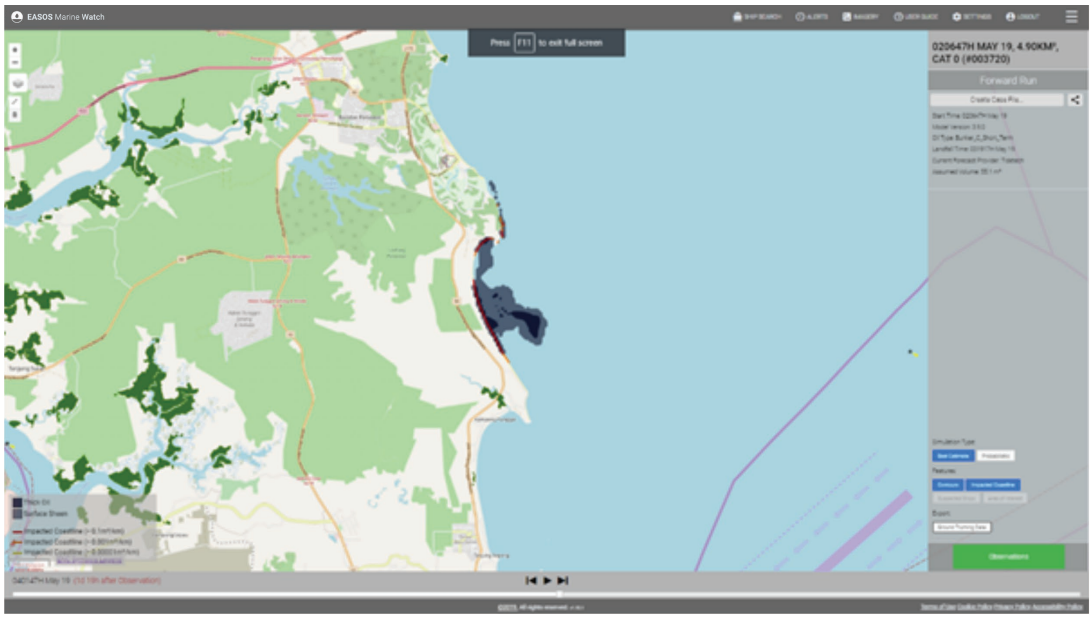
   In April of 2019, an oil spilt made landfall near Tg Balau, Kota Tinggi, causing significant environmental damage.

EASOS's post-project agency partners in Malaysia, KASI, via the Borneo Centralised Monitoring Centre, engaged with both the Marine and Environment Departments of the Malaysian government. EASOS was confirmed as identifying the slick position and the predicted site of landfall correctly *(as verified by the authorities)*. Through the additional capabilities within the system to model the likely origin of such slicks as well as the presence of vessels in the area at the same time, the authorities are using EASOS-derived information to support a proposed prosecution of the potential culprit.



Significant oil landfall forecast is forecast on Tanjung Balau

The event was publicised in the Malaysian press. Less than a month later, on the 2nd May at 06.47, EASOS generated another significant alert for the potential presence of oil. Furthermore, the predicted path of the 4.9km² slick over a period of 84 hours from initial identification suggested it may make landfall and have a significant financial and environmental cost to clean. A notification was sent via our Malaysian partners *(KASI)* to the authorities who acted immediately. Following a search for the slick by Malaysian Department of Maritime vessels, the slick was located, and capture / dispersal measures were implemented, preventing what could have been a major environmental disaster. Following the successful operation, the event was widely reported in the Malaysian press.



Projected path of the slick suggested major potential damage to nearby coastline

Booms released into the ocean and spreading of dispersants by the Malaysian Marine Department to retain and limit spread of the oil

3. **Support to operational management of Flood events during the 2017-18 monsoon season**

   During the development phase of the project, the Flood Watch service was used regularly by Malaysian agencies. EASOS services have been delivered daily by Catapult directly to the Malaysian agency, JUPEM, and directly integrated with the operating system of the Department of Survey and Mapping Malaysia *(DOSMM)*, which was able to overlay flood data onto its own base maps to identify infrastructures and roads that would be most affected. The information generated provided 'actionable intelligence' for operational management of flood events during the 2017-18 flood season. This was disseminated to the Armed Forces HQ Land Command, the HQ and Regional offices of NADMA, the Emergency Response Units of the State governments of Kelantan and Terengganu, and the Joint Agency Humanitarian Assistance and Disaster Relief *(HADR)* Group, to inform strategic positioning of troops, first responders, UAV *(drone)* operations, mobile hospitals and other assets for evacuation of flood victims. Areas in the Kelantan River Basin were placed on standby to evacuate people from their homes on four separate occasions as a result of accurate 'Yellow Alert' warnings generated via EASOS, though each time the extent of the flooding was eventually not of sufficient impact to warrant evacuation.

   EASOS Flood Watch offered a higher level of functionality and more rapid and accurate predictions than the existing manual system used by JUPEM for flood modelling *(PRAB)*. The latter used current rainfall data and rain forecast to find similar historic events in an Excel Spreadsheet to establish a prediction *(and has no visualisation tools)* – providing only coordinates of flood events.

   In January 2018 the Director of the Defence Geospatial Division of the Malaysian government agency, JUPEM, sent a letter to the Head of the International Partnership Programme at the UKSA, extending thanks to the EASOS team for the 'helpful and game-changing' services of EASOS in support of the Malaysian DOSMM's flood disaster operations and planning during recent flood events in east Malaysia *(Kelantan and Terengganu)*. The letter also states that continued cooperation of this kind will be beneficial in managing both natural and man-made disasters.