THE THIRD DIMENSION FOR SEARCH AND RESCUE

IfM Education and Consultancy Services

UNIVERSITY OF CAMBRIDGE

RNLI Lifeboats

REPORT INFORMATION

Contact information
For enquiries related to this report, please contact the RNLI at the following address:

innovation@rnli.org.uk

Authors
Hannah Nobbs, RNLI
Tim Robertson, RNLI
Dr. Will Roberts, RNLI
Dr. Clemens Chaskel, IfM ECS

Photo / image credits
Andrew Perryman
Hannah Nobbs
Tim Robertson
Dr. Will Roberts
Dr. Clemens Chaskel
Callen-Lenz
University of Southampton

Participating organisations
The following organisations attended the workshop:

ARPAS
ASV Global
Bluebear Systems
Bristol Robotics Lab
CAA
Callen-Lenz
DfT
EE
ESA
Frazer-Nash
Freedom Sensors
Human Factors Specialist
Insitu
Lockheed Martin
MCA
RNLI
Sentient
Skybound Innovations
SSRS
UAV Evolution
University of Southampton

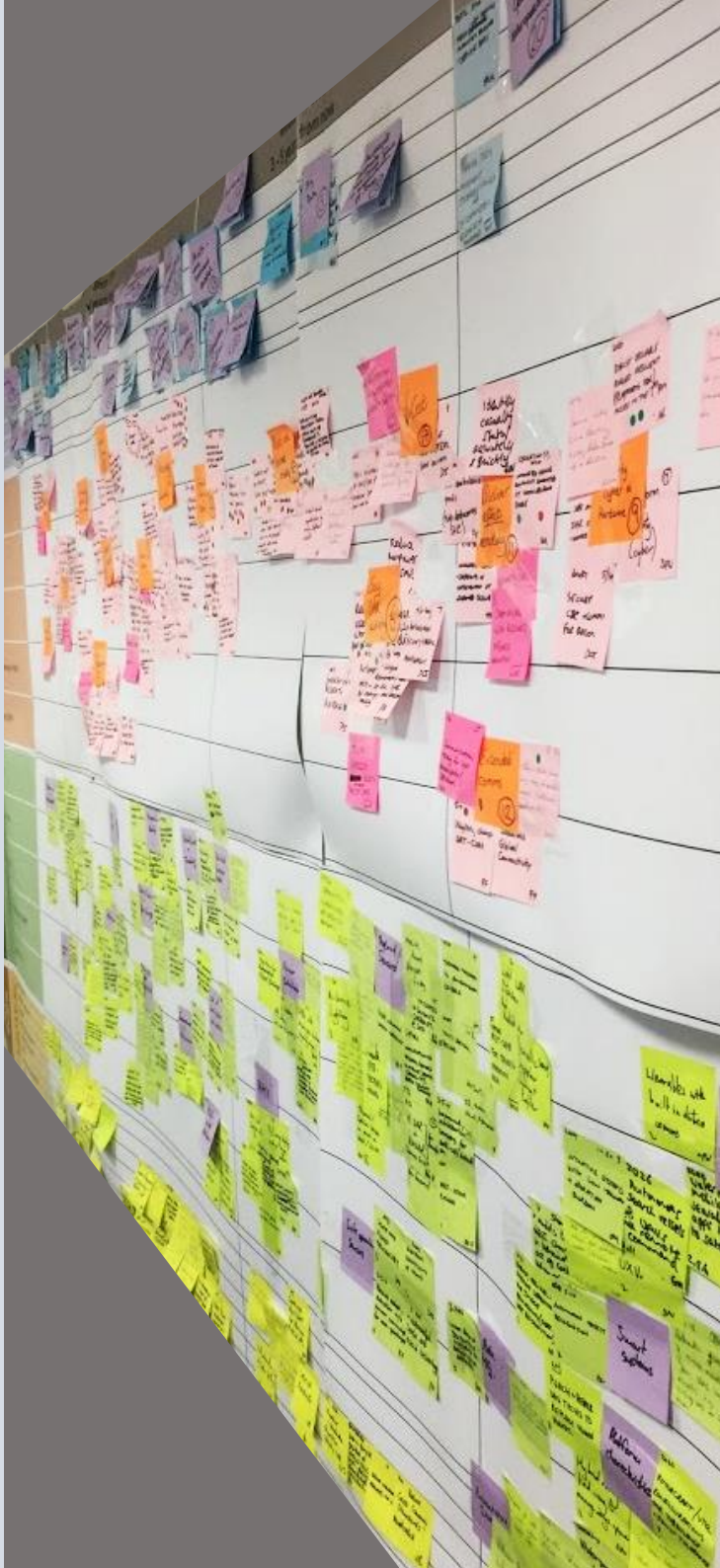
EXECUTIVE SUMMARY

This report summarises the outputs from the RNLI's roadmapping workshop on exploitation of the 3rd Dimension for Search and Rescue.

Roadmaps for the future exploitation of unmanned air systems for Search and Rescue (SAR) are presented with discussion and recommendations. These were developed from capturing the interactions between social and environmental drivers, the needs of the SAR Community and technology developments as identified by a mix of Subject Matter Experts from operators, industry, academia and governing authorities.

Starting from the increased affordability and miniaturisation of sensors, coupled with a growing change in attitude towards unmanned air systems, a critical path towards the routine use of autonomous systems in SAR has been identified. Through industrial partnerships to define standards and develop coherent systems and increased airworthiness management of platforms and operators, development of a regulatory framework is envisaged that supports routine unmanned flight beyond line of sight. This was agreed to be achievable for remotely piloted platforms in the medium term, followed by integration of autonomous platforms in a 10-year timeframe.

The potential for Unmanned Air Systems to enhance search capability, improve situational awareness, monitor areas of high risk and deliver survival aids/equipment are topics of particular interest to the SAR Community. These topics were developed into individual roadmaps, with recommended milestones to achieve the agreed vision for each topic in the shortest realistic timescale. Roadmaps for enabling topics – cyber security, public engagement, human centred design, safer SAR, multi-use business case and SAR asset integration are also presented.



CONTENTS

CHAPTER ONE
INTRODUCTION

Background

The Royal National Lifeboat Institute (RNLI) is the charity that saves lives at sea. Its vision is to halve the number of lives lost at sea around the UK and Republic of Ireland by 2024, whilst increasing its impact on global drowning. With such an ambitious, stretching target, it is essential that the organisation continuously challenges its strategy for achieving that end state. This is especially true when one considers the highly changeable landscape in which we operate – our lifesaving, prevention and funding operations are all potentially impacted by emerging socioeconomic and technological trends and drivers.

By identifying, understanding and interpreting emerging science and technology within the wider political, economic, societal context, the RNLI is able to make informed decisions on how to act. For example, the RNLI may wish to actively invest resource in developing a capability that exploits this technology, or partner with an organisation with similar goals to share the burden of exploring a new technological frontier. To ensure that the decision is not based on local, biased and parochial knowledge, the engagement of subject matter experts from across government, industry and academia, who can provide independent advice and insight is vital.

Through the process of Technology Roadmapping, the RNLI conducted a study in collaboration with industry and academia exploring the exploitation of technologies that will give search and rescue operators increased height of eye during SAR operations.

In a previous analysis of searches classified as ‘unsuccessful’, it was revealed that there is an opportunity for an improvement in the organisation’s search capability. A major objective of this work therefore, which was conducted in close collaboration with HMCG, was to define the space in which the RNLI could safely explore the exploitation of above surface capabilities to increase the efficiency of search whilst not impinging on the territory traditionally occupied by our SAR partners. Additionally, to get to the point of informing future assets strategy and concepts of operation, the RNLI also wished to identify ‘learning opportunities’ – small projects which would enable the RNLI to demonstrate the benefits of these technologies to the RNLI and wider SAR community- not only in terms of lifesaving and prevention capability but also in terms of cost savings and organisational efficiencies.

An additional driver behind this work was the need to bring some coherence to what is an extremely ‘noisy’ sector. In recent years there has been an explosion in the number of platforms purporting to have the potential to be used in search and rescue, resulting in multiple, unilateral purchases of products and services by organisations across the UK and ROI. By bringing together all operators involved in SAR in the UK and ROI, it was hoped that the risk of developing unique, bespoke systems would be reduced and economies of scale be realised by the coordination of needs early on in the procurement process.

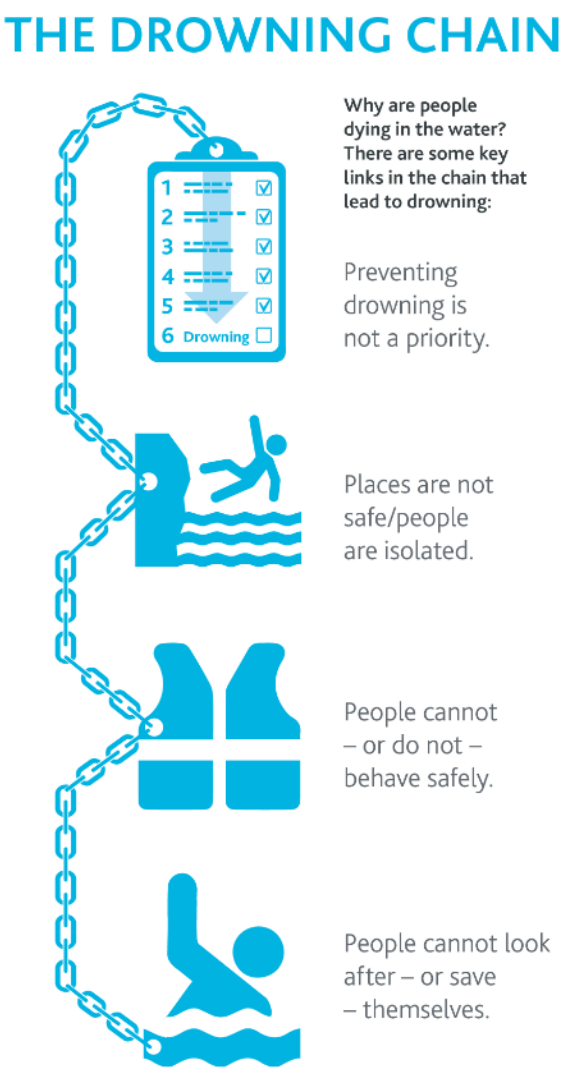


Figure 1: The 'drowning chain'

The work presented in this report gives an outline of the methodology followed, a precis of the roadmaps created through the process and a set of recommendations regarding what should be done next to get the RNLI and wider SAR community to the point of making an informed decision regarding the use of these platforms in the future.

Motivation for conducting this work

To invest in any technology development the SAR community need to understand the impact it is likely to have on lifesaving. The chain of events that leads to fatality from drowning, injury or exposure can be broken down into the following four 'links': Underestimating or being unaware of risks, unrestricted access to hazards, absence of adequate supervision, inability to save yourself or be rescued. This is commonly known as the 'drowning chain', as shown on the left.

Search and Rescue is the intervention at the last link, where all the opportunities for preventative action have been missed. This is where direct intervention comes at the highest cost with potentially significant risk to SAR operatives. A continuous driver for the SAR community is the reduction in time required to safely locate and navigate to a casualty and then faster safer rescue once on scene.

By delivering this rescue effect in a more efficient way, more effort and funding can be released to act on intervention during earlier parts of the chain.

During the course of providing lifesaving assistance, SAR personnel are routinely involved in what is colloquially referred to as "dull, dirty, and dangerous" activity:

- 'Dull' - long duration searches where fatigue can quickly have a detrimental impact on crew performance.
- 'Dirty' - infection risk from sea searches in contaminated areas such as around sewage outfalls and from in-water activity in the River Thames.
- 'Dangerous' - the hazards that rescue crews are routinely exposed to while undertaking search or rescue activity in challenging environments.

It was recognised by SAR operators that there is a need to understand how technology can reduce the impact these kinds of operations have on their people, who may often be volunteers. Reducing the amount of risk that operatives are exposed to during SAR operations is a high priority driver for the SAR community. The pertinence of these three types of activity is that in each operation an assessment has to be made as to whether the risk is proportionate to the benefit. The risk threshold will be much lower for a towing operation for example, versus an operation where there is a risk of loss of life.

CHAPTER TWO
THE LANDSCAPE OF THE THIRD DIMENSION FOR SAR

Scope

This document contains the findings of the technology roadmapping event only. Where appropriate, it does reference external material, but first and foremost, it is a true and accurate reflection of conversations and insights given by subject matter experts over the course of two days of technology roadmapping.

The problem space

The third dimension in the context of this technology roadmapping exercise refers to any unmanned platform or system that operates above the surface (water or ashore) to provide a search or rescue capability. The term 'third dimension' rather than 'air' is used to describe this operational space because it was deemed important that this exercise included masts, aerostats, unmanned air vehicles or satellites as potential solutions to increased height of eye. The physical sensor platform represents just one aspect of the system – equally important to consider was the operating models for these platforms and the management of sensor data to provide lifesaving effect.

Acronyms

SAR	Search and Rescue
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
RPAS	Remotely Piloted Aerial System
MALE	Medium Altitude Long Endurance
HALE	High Altitude Long Endurance
CONOPS	Concept of Operations
COP	Common Operating Picture
BVLOS	Beyond Visual Line of Sight
HAPS	High Altitude Pseudo Satellite

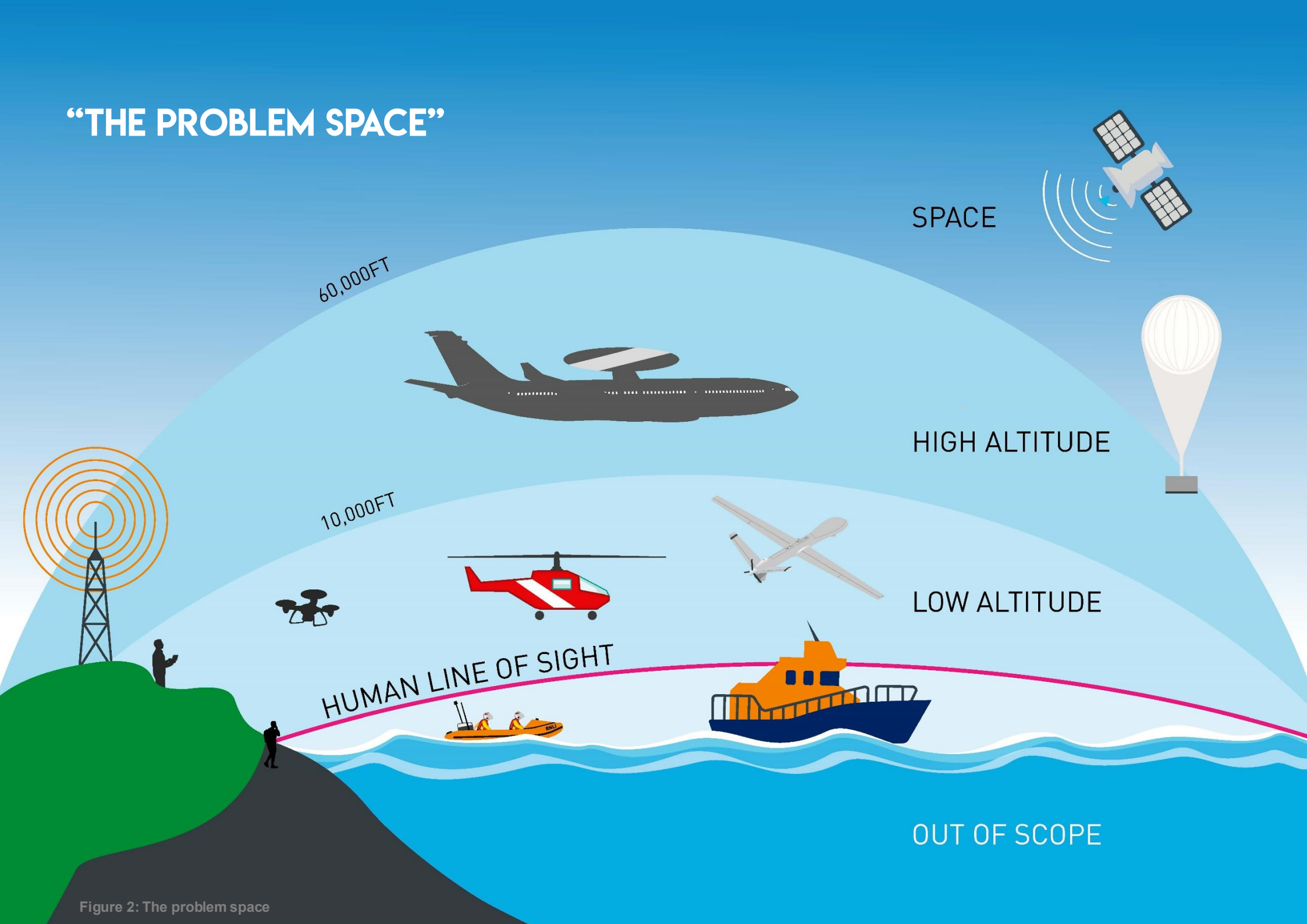


Figure 2: The problem space

CHAPTER THREE

METHODOLOGY

A detailed description of the methodology employed in the study, which is shown in Figure 2 on the right, may be found in the Annex.

25 experts from across industry and academia were invited to contribute their expert insights on the evolving landscape of the 3rd dimension. Over the course of two days, in addition to a preliminary survey, attendees were asked for their expert opinion on the five forces affecting technologies being used in the 3rd Dimension for Search and Rescue operations. Specifically, they were asked:

- What are the trends and drivers affecting this sector?
- What are the products and services being developed now and in the future to meet the UK SAR community's emerging needs?
- What needs to be achieved from a science and technology perspective to create these products and services?
- What are the barriers and enablers that must be tackled and promoted respectively, to make these achievements possible?

A combination of large and small group activities, each with review and feedback sessions, was used to validate results and opinions among the delegates.

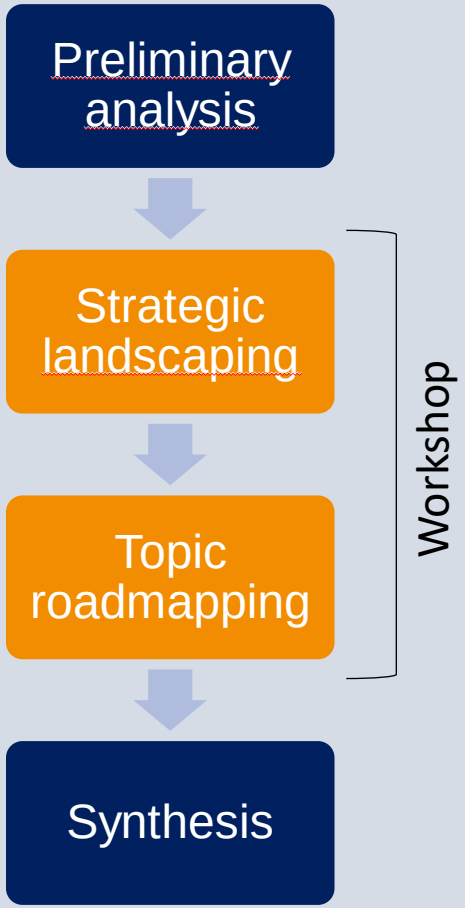
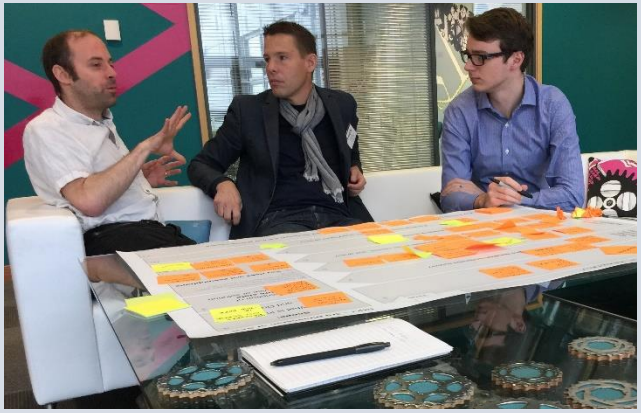


Figure 3: The process consisting of a workshop and back-office work.

Impressions of the workshop

Tim Robertson
RNLI

"It was rewarding to gather and host such a diverse group of stakeholders for this future technology roadmapping event and see them converge on a coherent vision over two days; a vision that will guide and facilitate the realisation of tangible benefits for the Search and Rescue community."



Richard Glyn-Jones
Sentient Vision

"I was encouraged to see the level of thinking within the group and I personally felt that there were some great ideas developed but it will be interesting to see how "multi-agency" can develop for the future. I will be very interested to see if we can collectively move the drone version of "Raynet" forward as I think this could be a fairly quick win especially in floods and coastal emergencies."

CHAPTER FOUR
DISCUSSION AND FINDINGS: THE LANDSCAPE

Technology Roadmap for the Exploitation of the Third Dimension for SAR

The roadmap of the overall landscape (Figure 4) shows the predicted interactions over time (from 2017 to 10 + years) between external trends, emerging technologies; and the services and solutions that would enhance future lifesaving capability.

Over the course of the workshop, themes emerged across the landscape. These are highlighted so that each theme can be followed through a narrative, linking the market 'pull' (trends and drivers, services and solutions) to the 'push' from emerging technologies.

The factors that act as enablers or barriers to reaching the vision are shown on the 'critical path'. These are the current gaps in our knowledge and therefore represent opportunities for development that need to happen in order for the exploitation of emerging technologies to be realised by the SAR Community. These gaps and opportunities span across the different themes identified, and are covered in more detail in the following sections.

It should be noted that the landscape developed during the workshop is an 'educated guess' on what the future may look like, based upon the knowledge and experience of the Subject Matter Experts that participated in the exercise. As such, all outputs of the roadmapping exercise are not to be considered definitive, but more as an invitation to engage in discussion and identify where further opportunities or gaps in knowledge may exist. Technologies have been placed on the roadmap in the timescale where there was consensus that the technology would be mature and affordable enough to be adopted for use in civil SAR.

Vision

Across the themes a coherent vision emerged for:

"***An affordable and effective SAR service, made possible through the routine use of autonomous systems in the third dimension; to deliver lifesaving effect in a way that compliments and enhances manned capability".***

Identifying Gaps & Opportunities

The ‘critical path’ towards realisation of the vision is highlighted on the landscape through a series of identified gaps and opportunities; that if tackled in the order presented will enable progress towards the vision in the shortest timescale.

Aerial search capability in the UK and Ireland is currently provided in the main by manned helicopters. UK SAR helicopters are tasked by HM Coastguard; predominantly for aerial rescue. It was confirmed by HM Coastguard workshop participants that to maintain availability of assets for rescue, a SAR helicopter is usually only deployed for search when there is a high probability of a rescue being required. This finding highlights the need for UK SAR to find a more cost-effective means of increasing height of eye and enhancing the service’s search capability.

Over the past few years an attitude shift has occurred in the aviation and SAR communities from a ‘manned first’ legacy mind-set to one where the potential for unmanned platforms to complement and enhance existing capability is recognised.

Increased affordability and miniaturisation of sensors; driven by consumer technology has resulted in individual onshore based operators, such as Mountain rescue teams and Blue Light Services (Police and Fire) exploring the potential for small unmanned platforms with EO and IR sensors to aid in search. This learning has been predominantly carried out within current CAA Drone Code. With some extended BVLOS trials and demonstrations conducted under CAA granted permissions in segregated airspace.

A significant enabler for widespread adoption of many technologies identified on the landscape is the development of agreed standards - for design of platforms, operations and of protocol for sharing/securing data. The definition of standards was considered vital to support the integration of autonomy with existing systems.

The routine operation of UAS beyond visual line of sight would bring a step change to the application of unmanned aerial systems for SAR. There are significant challenges to overcome before BVLOS flight is an accepted part of everyday operations. The most difficult of these challenges were identified as demonstration of sufficient reliability of platforms and systems to ensure safety of people and infrastructure beneath operations; and collision avoidance in airspace where the current rules rely on the principle of ‘see and be seen’ to separate traffic. The landscape reflects that it is thought that remotely piloted operations will be realised before autonomous BVLOS. The difference between these modes of operation is considered in more detail in the topic roadmap in following sections.

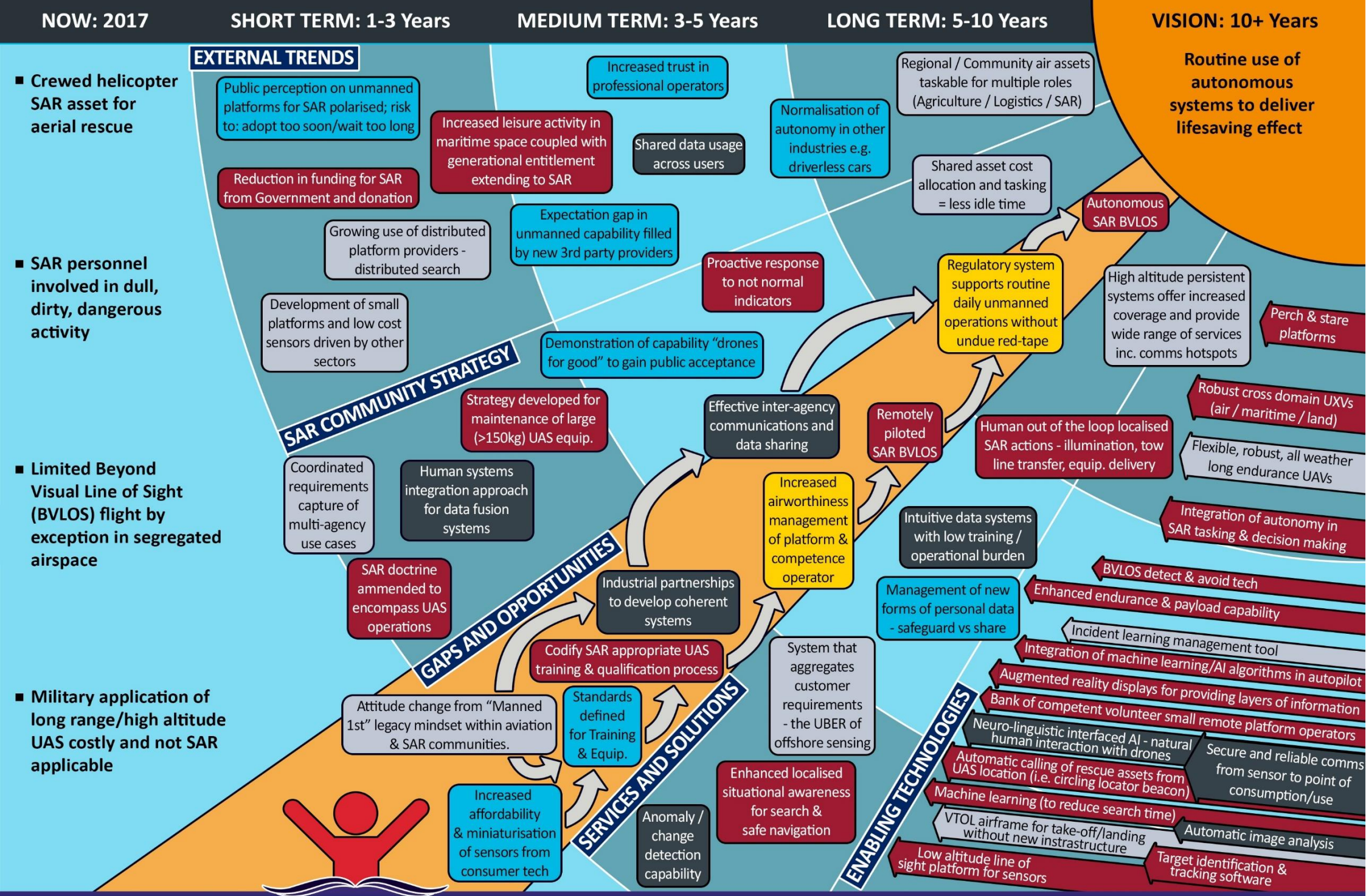


Figure 4: The future for exploitation of the third dimension for Search and Rescue, Royal National Lifeboat Institution, 2017

CHAPTER FIVE

DISCUSSION AND FINDINGS: TOPIC ROADMAPS

From the landscape, important topics were identified and explored in more detail. These are reported in the following section in two groups as shown below (Figure 6).

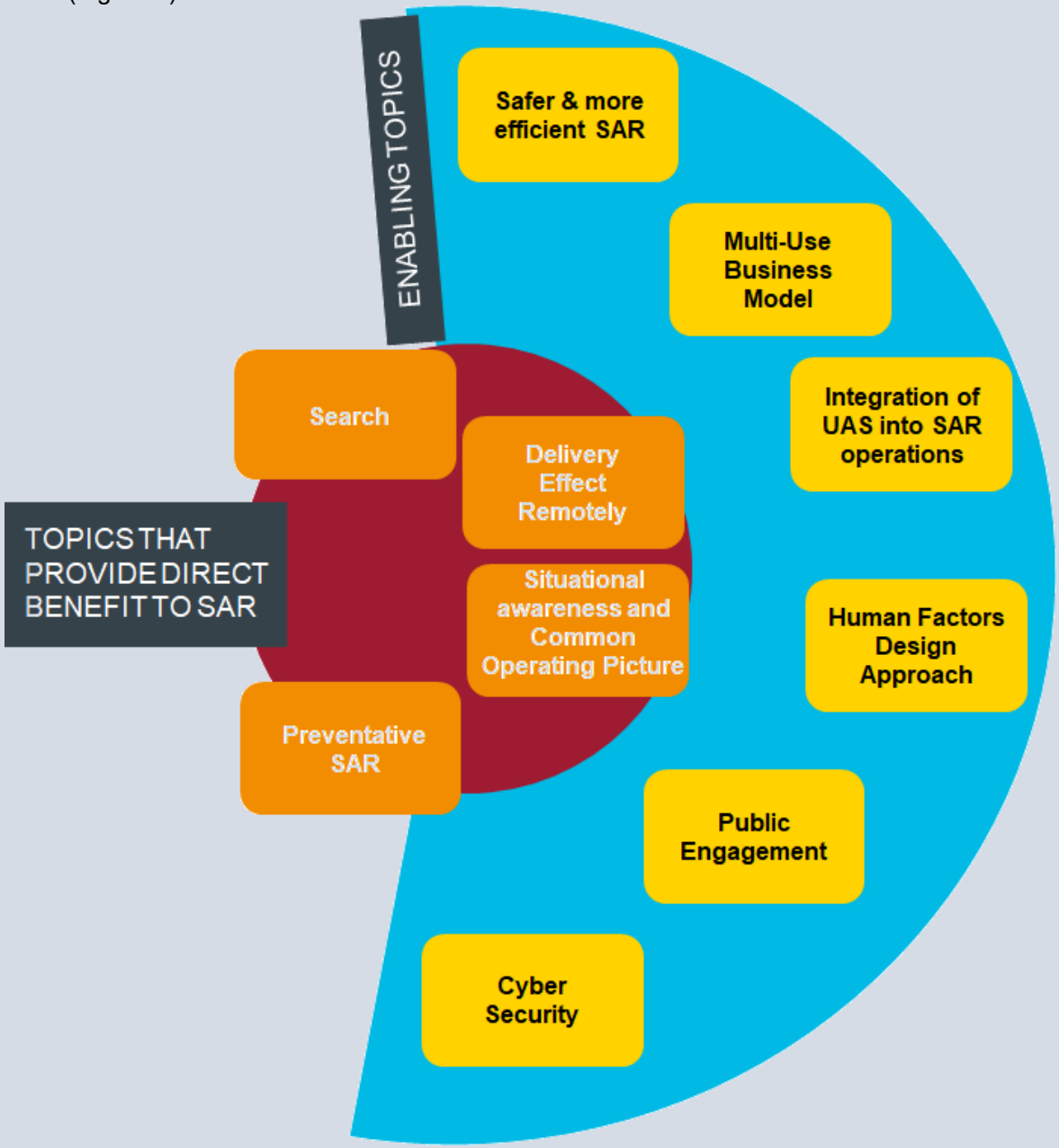


Figure 6: Topics identified in the strategic landscape

Topic Roadmap: Search

The drive to exploit UAS as a tool for searching is to increase the chance of survivability by reducing detection times through greater and more reliable coverage of a search area. Search of inshore areas is recognised as a challenge because there are issues of coverage with difficult terrain (cliffs, littoral zones etc.) where the 'nooks and crannies' of the coast can be too dangerous to fly a manned aircraft. Three sets of desirable platform characteristics were identified for different search tasks, from small to large scale:

1. Highly localised, rapidly deployable and multi-agency use 'eyes in the sky' with >2 hours endurance, <£10,000 approximate platform cost.
2. Systems that follow other assets such as lifeboats and aircraft with a radius of action >15 nm, > 5 hours endurance, <£100,000.
3. Long range systems with >400 nm range, >10 hour loiter endurance capability, <£250,000.

Many of the SAR operatives are volunteers, so it would be desirable if the piloting of these platforms was not overly burdensome.

Weather conditions are often used as a counter to any case for an unmanned air system. However, whilst it will be most advantageous for any system to be able to perform in high winds etc., attention must be drawn to when these systems will be used. For example, 91% of lifeboat launches conducted by the RNLI in 2015 were done so in winds <21kts, equating to a 'fresh breeze'. *[Final report of the Understanding 'Unsuccessful' Searches Project for the RNLI, Version: 2-0, 22nd December 2015]*.

In terms of collision avoidance and air space management, it would be desirable to have a UAV operating within the same search space as a manned helicopter, to optimise the search time. However, there would also be a need to exclude any air traffic that should not be there – such as drones operated by the press; and private individuals. UK SAR may wish to consider developing a common platform beacon of some description to enable automatic de-confliction or priority of de-confliction between assets in a search space.

There is a strong link to the Situational Awareness and COP roadmap for sharing the data from sensors to provide a location for rescuers to vector in on. Robust, reliable communications are key for disseminating information to multiple users and operators. To reduce cognitive burden, an on-board target acquisition system could prioritise targets for manned assets to investigate.

Multi agency collaboration is essential if UK SAR is to get the best value out of a search capability with UAVs. It will require on going collaboration, not only in terms of funding and operations and so on but also in terms of developing a joint concept of operations. If that can be agreed upon, it will mean that however the platform is applied, as long as it is operating under that understood concept of operations, we can get these operated to an understood standard more quickly.

Funding the development of unmanned platforms might well dilute other important assets and that could be a tricky balance to meet. The risk in the short to medium term is that the cost of

implementing new technology is seen as too high, therefore stalling progress.

With regards to Operational Risks, a key consideration is that there are multiple options as to how HMCG can conduct a search - if the wrong decision is made and HMCG commit the wrong resource, that could have a negative impact on perception of UAV usage – it is all very well getting there, but the asset will need to be able to do something as well – i.e. deliver an effect in addition to providing local situational awareness. There is also a risk that the programme takes much longer than initially anticipated due to regulatory barriers, the speed or lack thereof of decision making in government departments. However, the voluntary sector has much more flexibility, which is an advantage to UK SAR exploring this domain.

Steps to realising the vision:

Year 1- 3:

- Engagement of stakeholders in the SAR Community to understand split of tactical/strategic requirements and identify synergies in requirements.
- Development of a set of design reference missions that can be used to assess performance characteristics of different technologies.
- Localised technology trials and demonstrations to inform end user requirements.

Year 3-5:

- Roll out of localised platforms.
- Multi-agency trials and demonstrations of longer range platforms.
- Evidence of effectiveness gathered to enable refinement of strategic requirements.

Year 5+

- Regulations support routine flight BVLOS in unsegregated airspace.
- National roll out of long range capability.

TOPIC ROADMAP: SEARCH

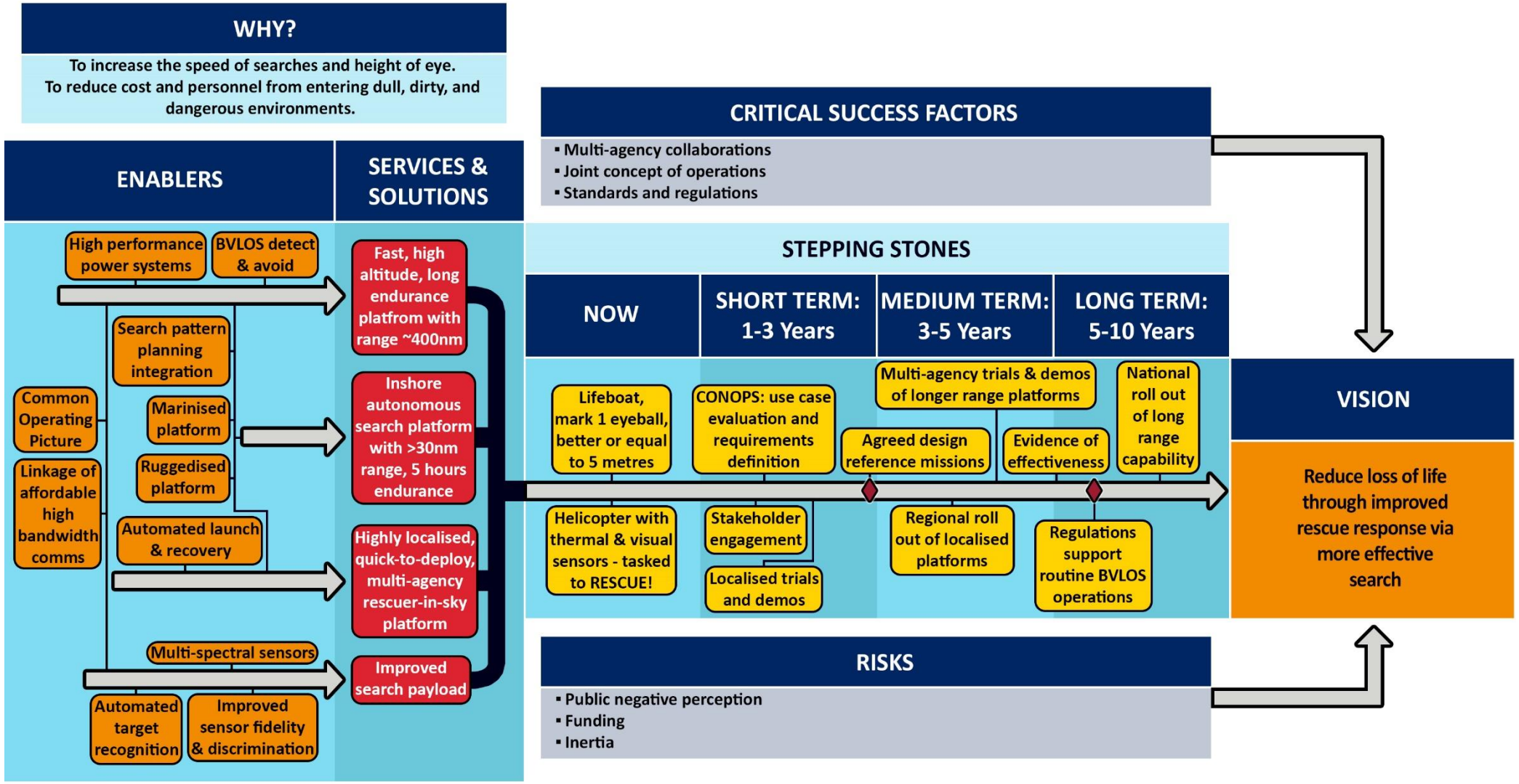


Figure 7: Topic Roadmap "Search"

Topic Roadmap: Situational Awareness and Common Operating Picture (COP)

In the majority of instances, situational awareness for SAR is currently highly localised and limited by individual platforms (helicopter and lifeboat) relying on voice communications and AIS for data dissemination in real-time between SAR partners. Greater situational awareness for operators would improve the quality and speed of rescue by driving authority for decision making down to SAR personnel on scene.

The desired future state is one where a common operating picture for SAR enables more lives to be saved with lower risk to personnel and reduced operating costs.

In scope for this topic roadmap is the acquisition and exploitation (collection, storage, sharing and visualisation) of all relevant data for enhancing SAR effect.

The fundamental need is to share data with the relevant people in a timely manner.

To achieve a coherent and connected data enterprise, the SAR community need:

- To identify relevant data sources and how to harvest useful elements.
- Robust communication systems to route data from one point to another.
- Processing and archiving tools for secure data storage and retrieval for secondary, post-mission analysis. This is for evidence but also to inform future CONOPS.
- Appropriately trained people.
- Visualisation tools to present information to the user in a way that reduces cognitive workload. The intuitive presentation of information is particularly vital to reduce the training burden of volunteer operators.

The roadmap highlights the growing automation of object detection, recognition and tracking; and the increasing use of machine learning and analytics platforms to process large amounts of data. This includes drawing conclusions and inference from large data sets comprising real-time data overlaid on historical inputs. In the short term, processing of data is 10% machine and 90% human which gradually becomes 90% machine, 10% human as processing technology matures.

In developing requirements, the SAR community has the opportunity to learn from prior experience.

This trend is more a reflection of the belief that the number of decisions made by humans will reduce as machines develop autonomy to operate, allowing a reduction in cognitive loading in order to enhance the quality of more critical decisions by the human in the loop, which has been hard-won in the defence and law enforcement sectors.

Achieving connected data for greater situational awareness was identified as a joint enabling capability and therefore UK plc was believed to be the main source of funding for development of infrastructure. A critical success factor is the establishment of joint Key Performance Indicators across several different departments within UK plc. The UK SAR community would then fund their elements of technology to connect to that enabling capability delivered by central government.

Steps to realising the vision:

Year 1- 3:

- Development of common data standards to enable fusion of disparate data sources to create one common operating picture
- Demonstration of benefits of standards through technology demonstration
- Adoption of common data standards and formats to ensure interoperability of systems
- Development of datalinks to share AIS tracking data between SAR partners.

Year 3-5:

- Integration of data feeds from unmanned platforms
- Increasing automation in decision making based on common operating picture

Year 5+:

- Widespread use of agreed standards and architecture in UK SAR operation

TOPIC ROADMAP: SITUATIONAL AWARENESS AND COMMON OPERATING PICTURE (COP)

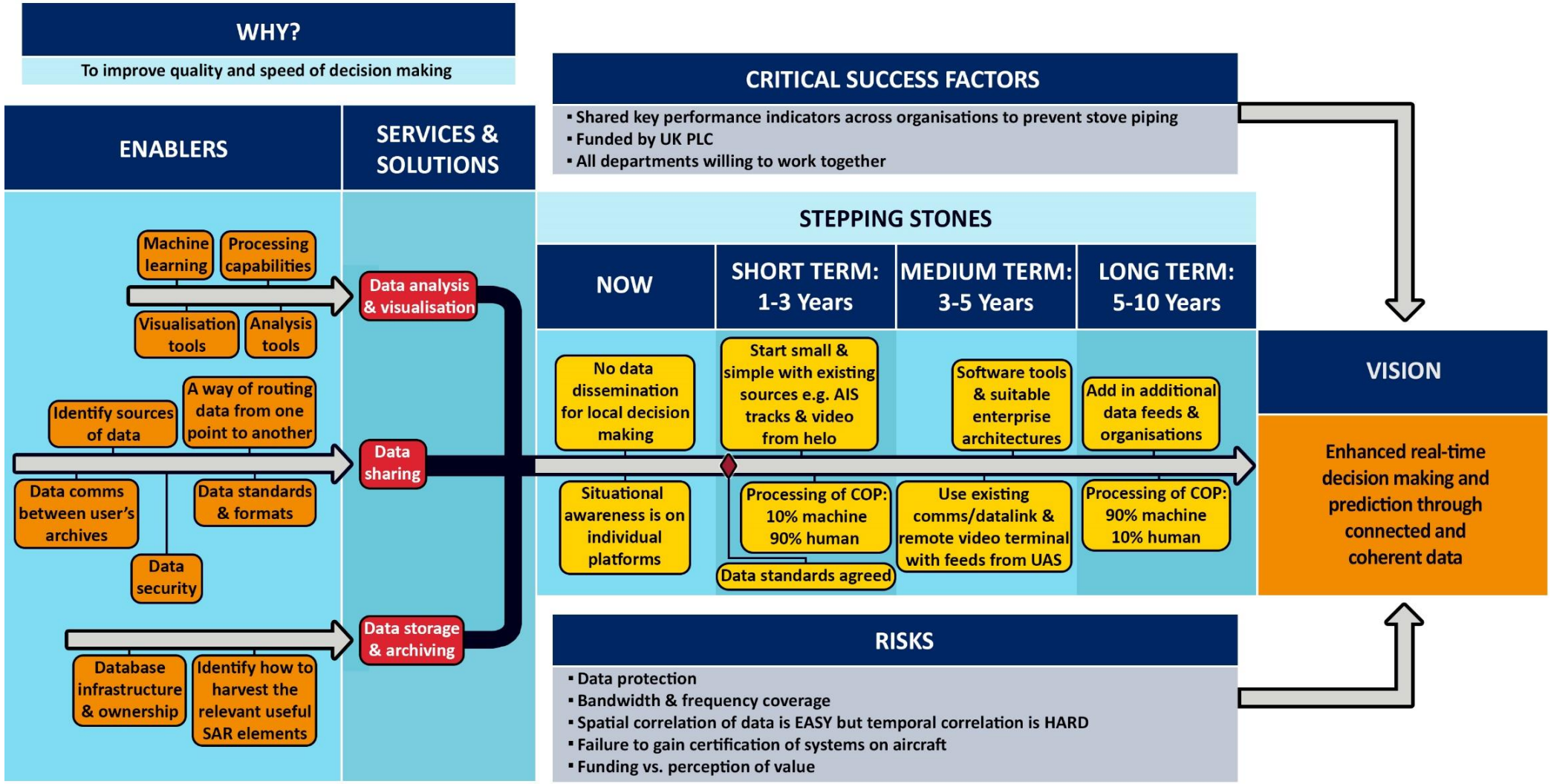


Figure 8: Topic Roadmap "Situational awareness and common operating pictures (COP)"

Topic Roadmap: Delivering Effect Remotely

The scope for this topic roadmap is to help someone in distress to be able to survive until rescue arrives.

Delivery of lifesaving effect could include:

- Flotation
- Heat sources
- Beacons for location / tracking
- Lighting or illumination
- Defibrillators
- Rescue equipment transfer between teams (mountain/ flood)
- Voice (for communication of advice)

This is a typical beyond line of sight activity, therefore the establishment of safe, routine flight BVLOS is a critical enabling factor in delivering lifesaving effect remotely.
The platform that delivers effect needs to have sufficient payload capacity and suitable range and endurance performance to reach the scene in a timely manner.

How this is achieved can follow two distinct paths:

Autonomously

- Requires reliable autopilot intelligence to recognise the incident scene and respond quickly to dynamic factors to determine what to do. Also with sense and avoid capability.

Remotely Piloted

- Demands a robust communications link for real time control.
- Within the remotely piloted option, there is a graded level of pilot control, allowing the operator to be kept in the loop to varying degrees. For remote piloting an uninterrupted comms link with very short delays is required. This uninterrupted comms link is not necessary for a platform that is fully or partially autonomous using GPS etc.
- The roadmap reflects the consensus that the remotely piloted route is likely to be achievable first, as a stepping stone towards greater autonomy as the elements of technology are already available. The critical enabler is to demonstrate assurance of collision avoidance and reliability to enable routine operations beyond line of sight.
- Autonomy has significant advantages in the SAR environment because it removes the need to train extra personnel or burden existing personnel with additional training to pilot the system. Furthermore, it could potentially feed data into existing scenario management systems, thus not increasing the cognitive burden on operators.
- More research is needed in this field because there is not yet an ‘off the shelf’ autonomous system capable of differentiating between a canoe and a head in the water for example

It is believed that all the proposed scenarios (e.g. delivery of flotation devices) are good candidates for easy proof of concepts. They can be demonstrated close to home and there is no need to go beyond visual line of sight to demonstrate incremental developments and introduction of capability.

Holding a competition based around the delivery of items for SAR could be a way to attract funding as it would provide a mechanism to demonstrate something that is very tangible. This approach would also provide an opportunity for engaging the general public. A comparative example would be the UAV Challenge in Australia [1] whereby a challenge is set and a prize fund awarded to the highest performing team according to specified goals.

Other funding could be available via manufacturers who may consider conducting development for SAR applications as part of their wider strategy for other commercial exploitation routes. E.g. leveraging technology used for retail delivery in platforms used for SAR applications. Working with the SAR community as 'extreme users' could yield interesting design opportunities exploitable in other sectors.

Steps to realising the vision:

Year 1- 3:

- Demonstration of concepts through gaming and competition to encourage development

Year 3-5:

- Roll out of localised remotely piloted platforms

Year 5+:

- Flight trials to prove the concept of payload delivery by autonomous platforms.

[1] https://uavchallenge.org/medical-express/

TOPIC ROADMAP: DELIVERING EFFECT REMOTELY

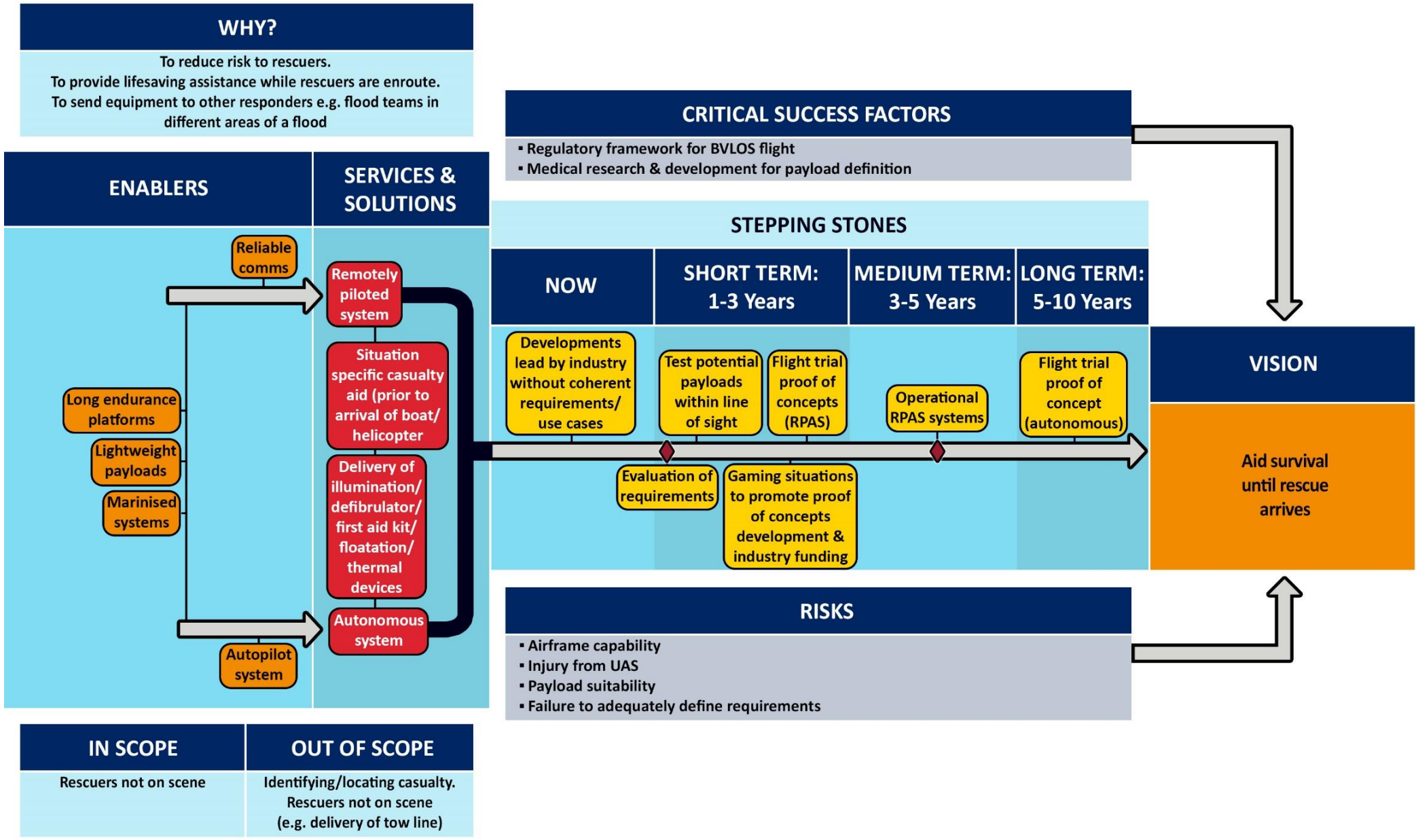


Figure 9: Topic Roadmap "Delivering effect remotely"

Topic Roadmap: Monitoring for SAR

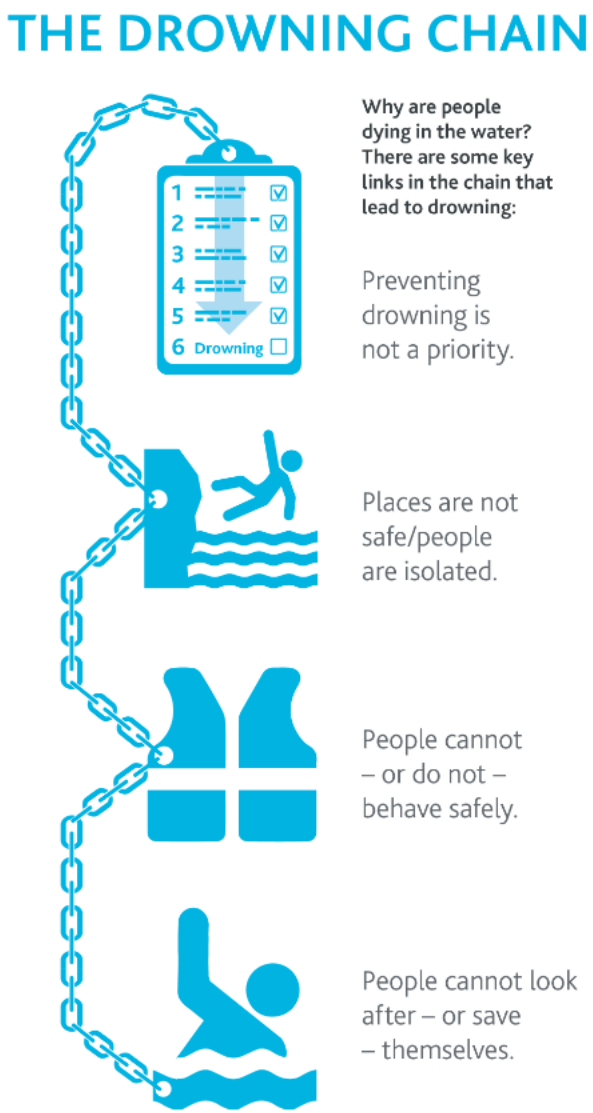


Figure 10: The drowning chain

The drowning chain (Figure 10) highlights that search and rescue is the last chance to intervene when other chances to prevent an incident occurring have been missed. By its nature, this is a dangerous activity that exposes SAR crews to high levels of risk.

The scope for this topic covered early warning opportunities, before a situation develops into an incident. It was considered out-of-scope once a search is required.

Preventative action via monitoring of high risk areas such as coastlines and flood plains could pre-empt the need for search and rescue activity through identification of potential problems before they develop.

To provide effective monitoring using fixed or localised assets, blackspots would need to be identified which would enable key risks and causes of incidents to be understood and costs to be managed.

As more data is collected, normal/not normal indicators have the potential to alert that early intervention is required, for example, damage to physical safety infrastructure.

The full range of platforms was considered applicable to this topic, from thermal/electrical optical sensors on masts and aerostats to high altitude, long endurance platforms.

Steps to realising the vision:

Year 1- 3:

- Engage with local communities to understand root causes of incidents
- Identify areas of high risk.
- Understand technology options

Year 3-5:

- Model the through life characteristics of different options.
- Review transversal issues (Training, Equipment, Personnel, Information, Concepts and Doctrine, Organisation, Infrastructure and Logistics)
- Understand maintenance models
- Analyse and predict the reduction in callouts against design reference missions
- Scaled rollout of capability.

TOPIC ROADMAP: MONITORING FOR SAR

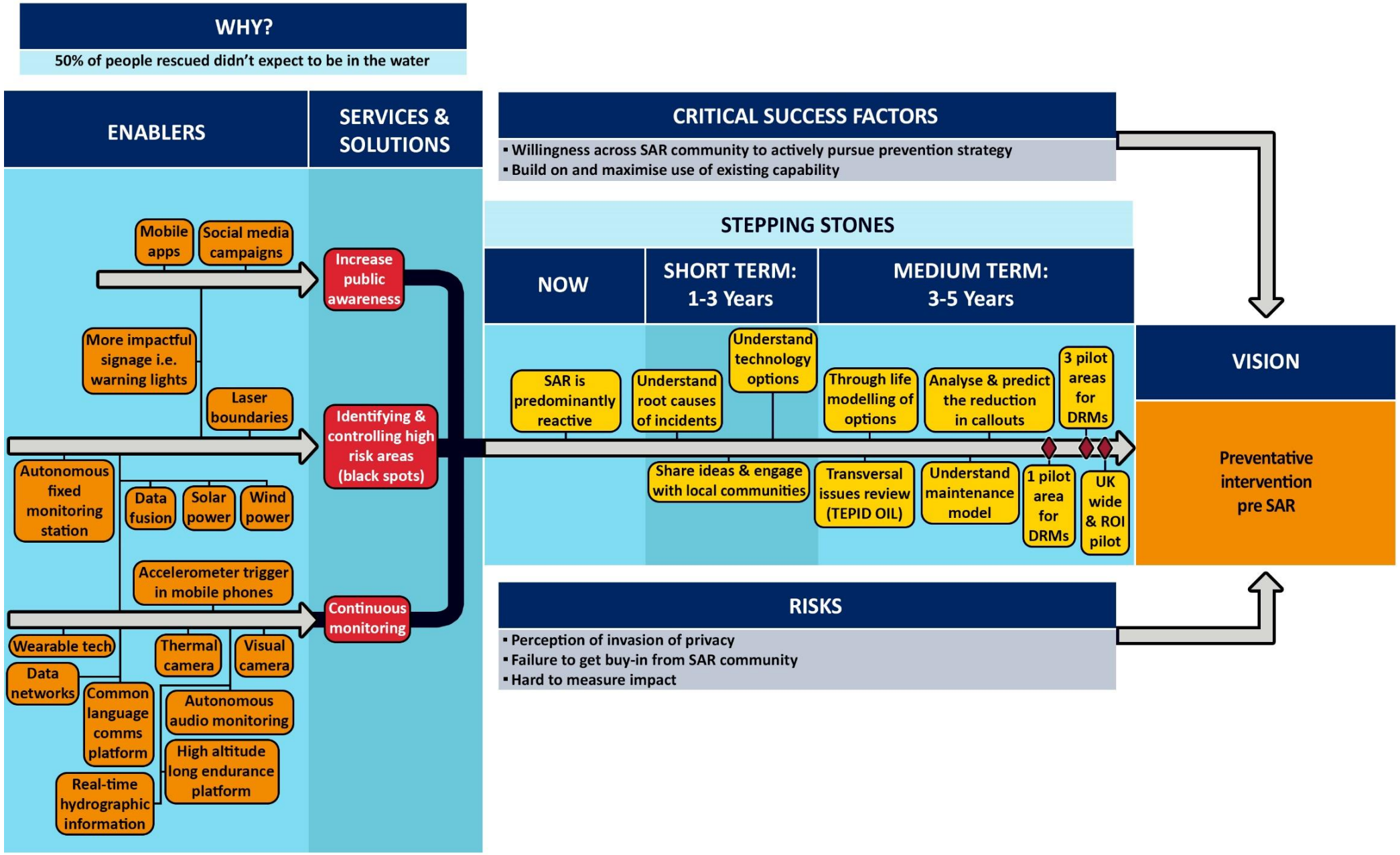


Figure 11: Topic Roadmap "Monitoring for SAR"

Topic Roadmap: Public Engagement

The public's perception of new technology is a vital consideration when introducing it to market and the introduction of UAS or similar to a public facing service such as search and rescue is no exception. When also considering that UK and ROI search and rescue operations involve volunteers, serious consideration must be given to how the introduction of these technologies will impact these parties and how this is communicated and managed.

'Drones' have an interesting relationship with the media, depicted as anything from machines of war to harmless children's toys. It is vital therefore, that the UK SAR community has a well-defined community engagement plan that takes external stakeholders through a journey of enlightenment and secures us buy in and endorsement of the use of these systems for lifesaving.

It is envisaged that the public engagement programme will continue for the life of the capability, but activity will be ramped up from zero over the first three years.

Partnership-working will be an essential part of this programme and collaboration with organisations that understand the boundary between technology, people and culture will be extremely beneficial.
The vision for this public engagement project is to get the public thinking of these systems in the same way that they think of as another class of lifeboat: "as a routine, normalised, accepted thing for them, that it's a natural thing for the RNLI / UK SAR community to be doing".

Steps to realising the vision:

Year 1:
Communication via the chosen channels, of the UK SAR community's planned programme of activity and its decision to explore the benefits of the capability.

- Public engagement events demonstrating capability and benefits to operational scenarios (Hacks / STEM events etc.)
- Public consultations to gather feedback and opinion on UK SAR exploiting this technology.

Year 2-3:

- Communication of vision for capability, taking lessons learnt and feedback in Year 1
- Continued demonstration of capability, including critical safety aspects and benefits
- Communication of findings and any plans for investment at a National or organisational level for scaling up of capability

Year 3+:

- Use new capability as platform for engaging new volunteers / supporters
- Continued engagement and feedback from key stakeholders

TOPIC ROADMAP: PUBLIC ENGAGEMENT

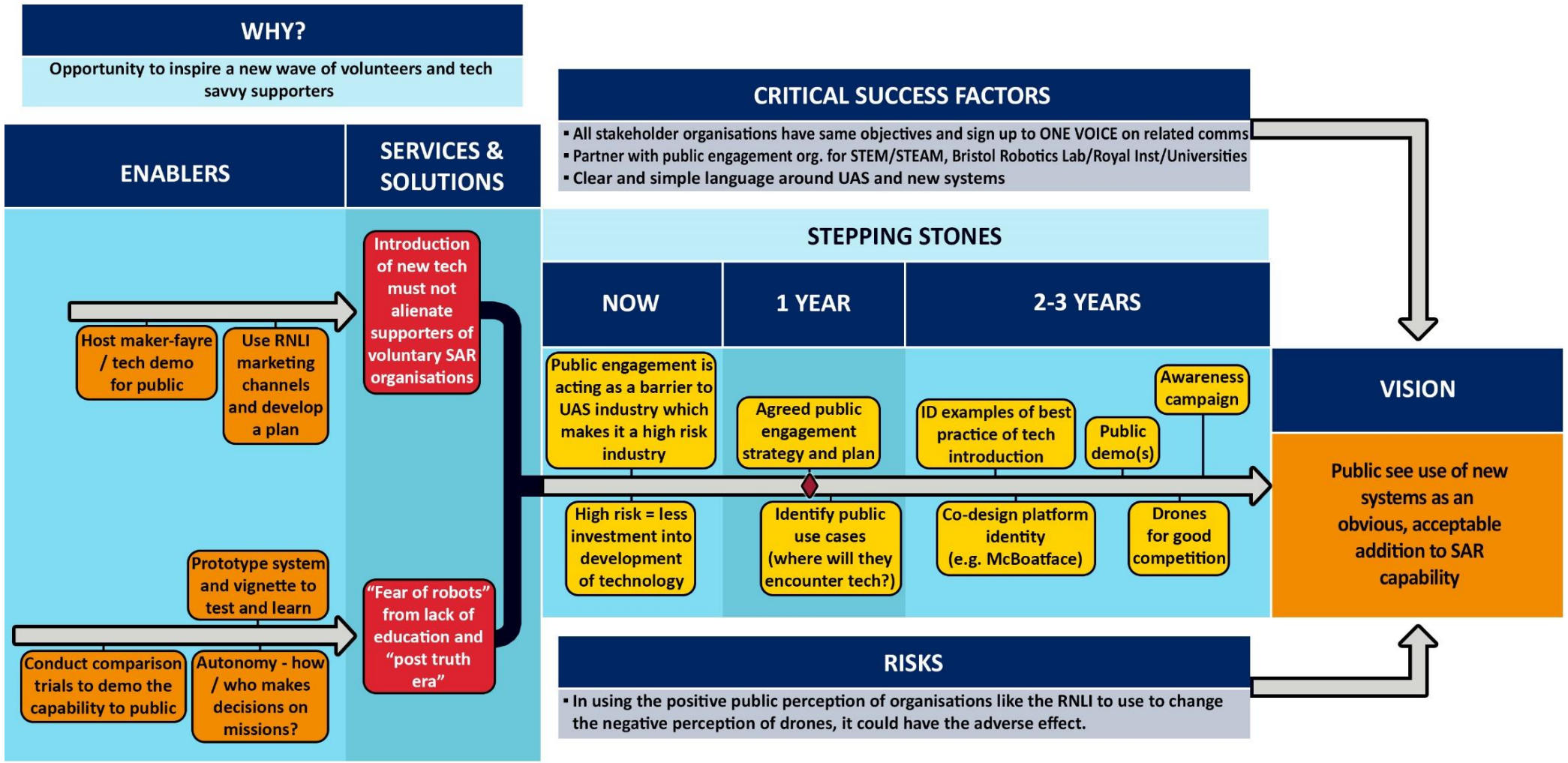


Figure 12: Topic Roadmap "Public engagement"

Topic Roadmap: Multi-Use Case

The primary driver behind a multi-use case is cost. In an increasingly austere financial environment, all avenues must be explored to reduce the financial burden of implementing and managing these capabilities through-life. It is proposed that this could be achieved via:

- Leveraging economies of scale by implementation of common platforms, which can be modified with application specific hardware or software plugins
- Sharing of same platform / system for multiple applications – e.g. SAR plus agricultural mapping
- Centralised and co-ordinated supply chain

Beyond UAVs, higher altitude platforms were discussed, which have for many years been exploited by multiple agencies. Platforms such as satellites, Cube SATS, HAPS (High Altitude Pseudo Satellites) all offer the potential of delivering persistent surveillance capabilities, but along a longer timeframe and currently, at a higher cost. However, with the rapidly expanding LEOSAT constellation, these barriers could soon be overcome.

With the multi-use business model comes the challenge of ownership, governance and priority. For this to work, these governance mechanisms must be put in place early on in consultation with potential platform partners.

Partners may include but are not limited to:

- HMCG
- Royal Navy
- RNLI
- Oil and Gas organisations
- Environment Agency
- Border Force
- Marine Fisheries Agency
- Mountain Rescue
- Lowland Rescue
- Police

How the platform is subsequently supported financially depends on the various use cases and there are multiple models. Early engagement with potential stakeholders will reveal the candidate options.

Given the critical nature of SAR operations in the context of emergency response, agility and flexibility, especially in relation to regulatory conditions is essential.

In this multi-use business case however, a critical consideration is *who?* Who is going to develop this business case and co-ordinate the requirements of all the participating organisations?

Each organisation will want their requirements to be met as a matter of priority, so leadership and accountability will be a critical success factor.

Whilst UK SAR and other potential stakeholders seek to find the most cost effective, parsimonious route however, industry will continue to develop products and services and continue to sell these to customers. They are driven by financial performance whereas government is driven by cost saving. UK SAR needs to be mindful of this and hence, to move quickly and not miss the opportunity to leverage and influence the development of these technologies to save life.

It is felt that the introduction of this capability to UK SAR organisations will need significant thought and application of change management methodologies – particularly when one considers the human implications of these technologies – it's likely to affect public perception and potentially the role of operatives and volunteers.

Novel models of financing a multi-use platform are possible, including leveraging savings on insurance, but multiple stakeholders will result in a reduced financial burden.

Whilst government agencies can be 'coached' by industry and academia on the right approach, the agencies must take the lead and be accountable for these programmes.

The absence of leadership in this area and a lack of accountability may result in a failure to gain economies of scale and a missed opportunity.

TOPIC ROADMAP: MULTI-USE BUSINESS CASE

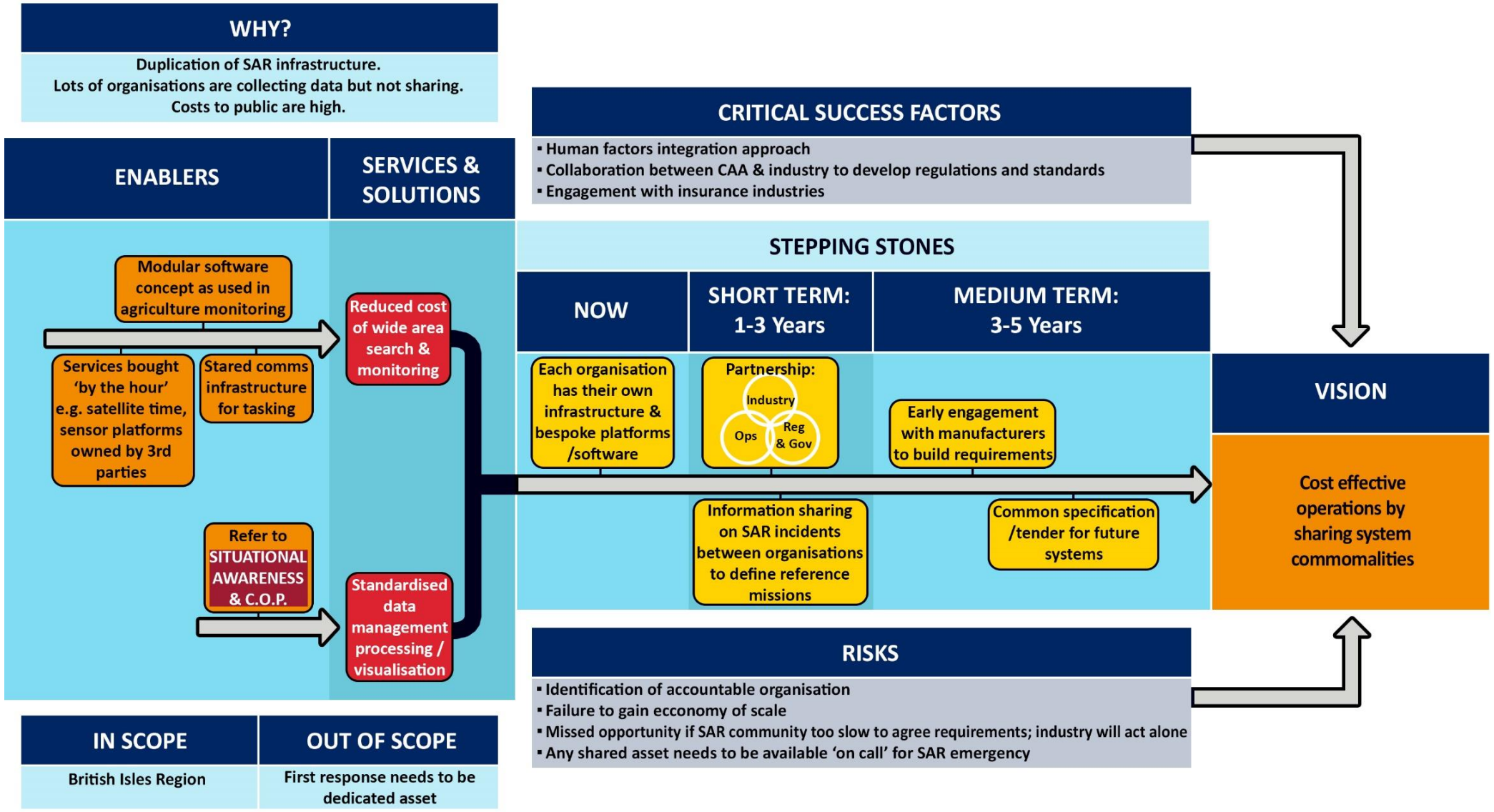


Figure 13: Topic Roadmap "Multi-use business case"

Topic Roadmap: Integration of UAS into SAR Operations

This topic was identified as an evaluation process rather than a physical output.
The starting point is the hypothesis that an unmanned system can help deliver capability to release and offload the tasking on manned or direct intervention platforms. An example of this is a UAS providing an advanced search function while a helicopter/boat is *en-route*.

There is not yet an 'Omni-drone' that can perform every function needed for SAR. Therefore, a mix of manned and unmanned platforms is required. The unmanned category can be further split into small and large platforms, which can be roughly aligned to an inshore and offshore mix.

To compare the performance characteristics of different platforms, a number of prescribed use cases, or Design Reference Missions are required.

These can be used to evaluate what that potential task is and how that task is to be split up to be serviced by a number of different platform mixes.

The output of the analysis would be an optimum asset mix to achieve the maximum SAR performance for a given cost.

A standard capability across agencies was identified as an important step to maximising SAR effect. For example, different agencies may have dissimilar platforms, but there needs to be a common way of combining the output from each platform. This topic links closely to the situational awareness and COP roadmap.

One of the operating models discussed during the workshop was the potential to use volunteers with unmanned systems the way that the RAYNET organisation works, either to evaluate a concept or provide a capability.

To achieve optimum capability, two critical success factors are the robust modelling of asset characteristics and subsequent requirement definition and refinement.

TOPIC ROADMAP: SAR ASSET INTEGRATION

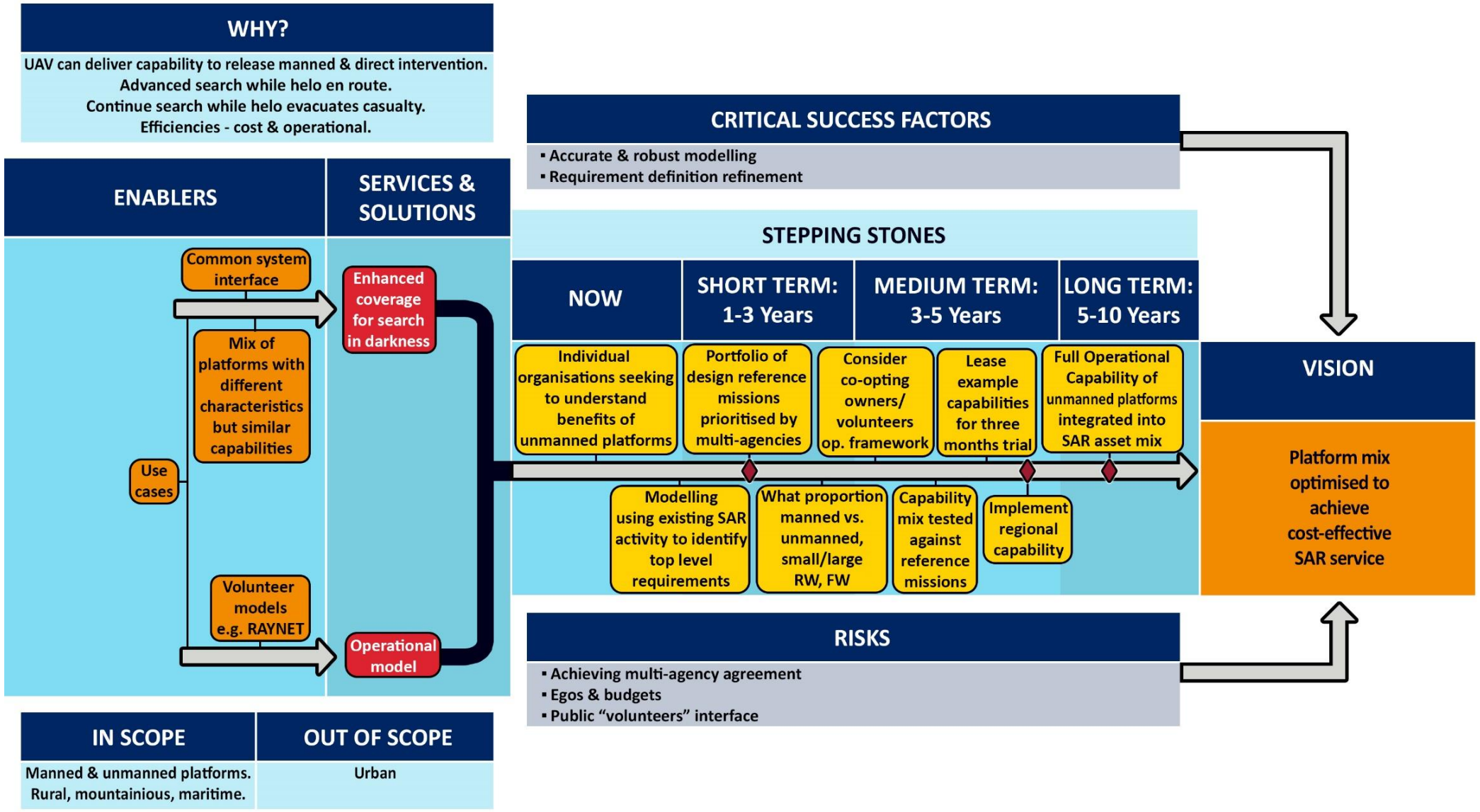


Figure 14: Topic Roadmap "SAR asset integration"

Topic Roadmap: Cyber Security

The timeline for this topic is concentrated in the short term, as the enabling technology already exists.

Effective cyber security is a balance between maintaining the integrity of command, control and communication systems, while ensuring that the system is still usable for the purpose it is intended for. The success of cyber security processes is marked by an absence of data loss incidents.

SAR personnel and assets need to be protected from data loss, and operating organisations need to protect their brand identity from negative media coverage of any data loss.

Secure real-time communications with the platforms being used for SAR is important, but so is the passing of data between different agencies. To achieve a robust, safe and secure system there needs to be some physical security measures (barriers and fences), some security software (encryption), processes and procedures for data handling between organisations and appropriate training of responsible personnel. Best practice from law enforcement and the defence sectors could provide guidance to the SAR Community.

UK SAR organisations' Cyber Security Strategy needs to be extended to include UAS platforms.

TOPIC ROADMAP: CYBER SECURITY

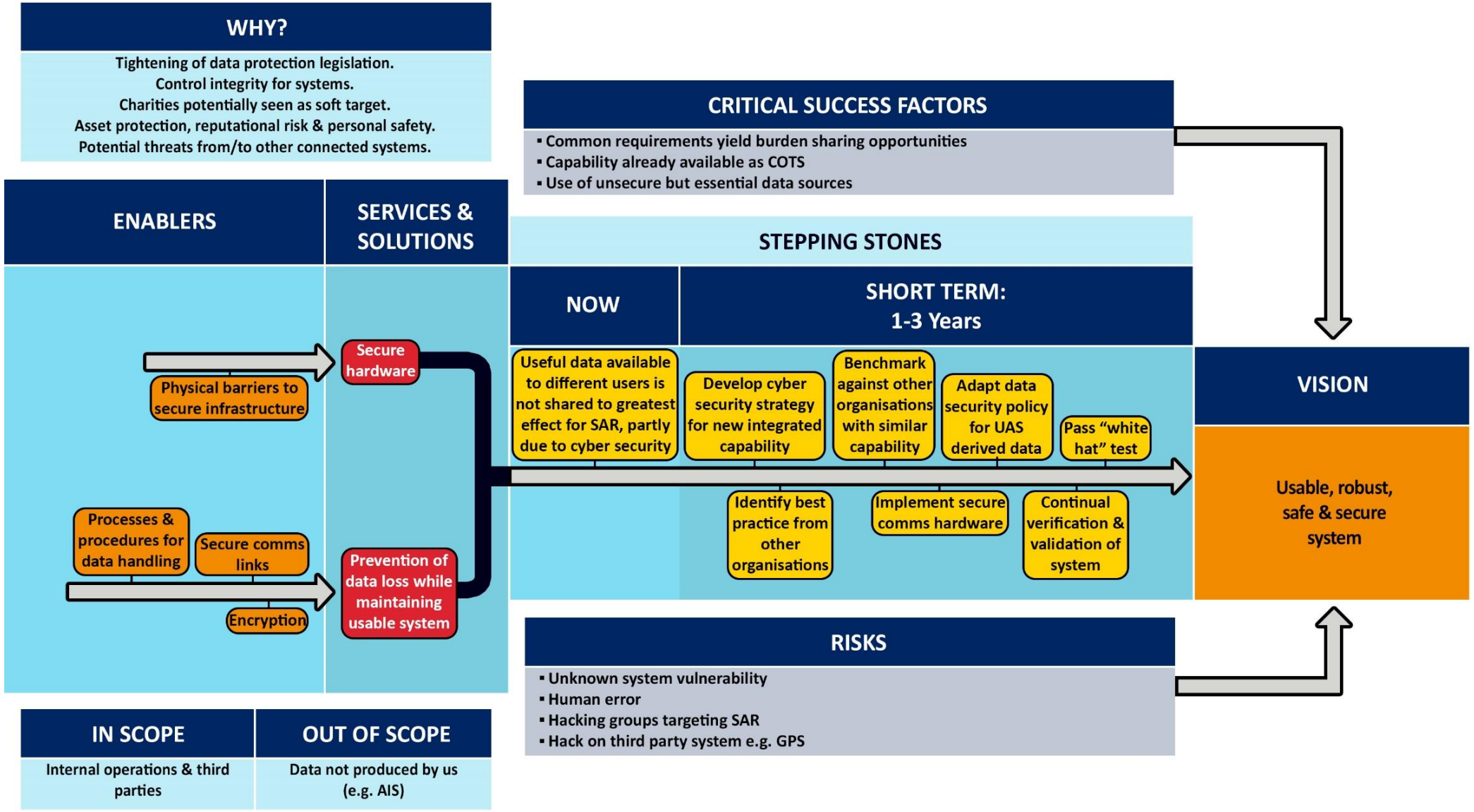


Figure 15: Topic Roadmap "Cyber security"

Topic Roadmap: Safer SAR

This topic roadmap links closely to the four direct benefit topic roadmaps by collecting together the services and solutions needed to reduce human exposure to risk during SAR activities.

An integrated approach to exploiting technology for safer SAR is necessary because it needs to apply across multi-agency operations and is likely to involve a mix of different platforms. Localised solutions for specific risks, such as removing pyrotechnics for illumination were seen to be achievable goals in the short term. In the medium term, wearable technologies have the potential to improve situational awareness for both casualties and rescuers; and data from satellite earth observation tools and high-altitude platforms lend themselves to monitoring for preventative action pre-SAR. Unmanned delivery of survival/rescue equipment could also benefit rescue operations for flood or mud rescue teams.

This is a highly collaborative topic with multiple stakeholders. Partners may include but are not limited to:

- HMCG
- Royal Navy
- RNLI
- Oil and Gas organisations
- Environment Agency
- Border Force
- Marine Fisheries Agency
- Mountain Rescue
- Lowland Rescue
- Police

TOPIC ROADMAP: SAFER SAR

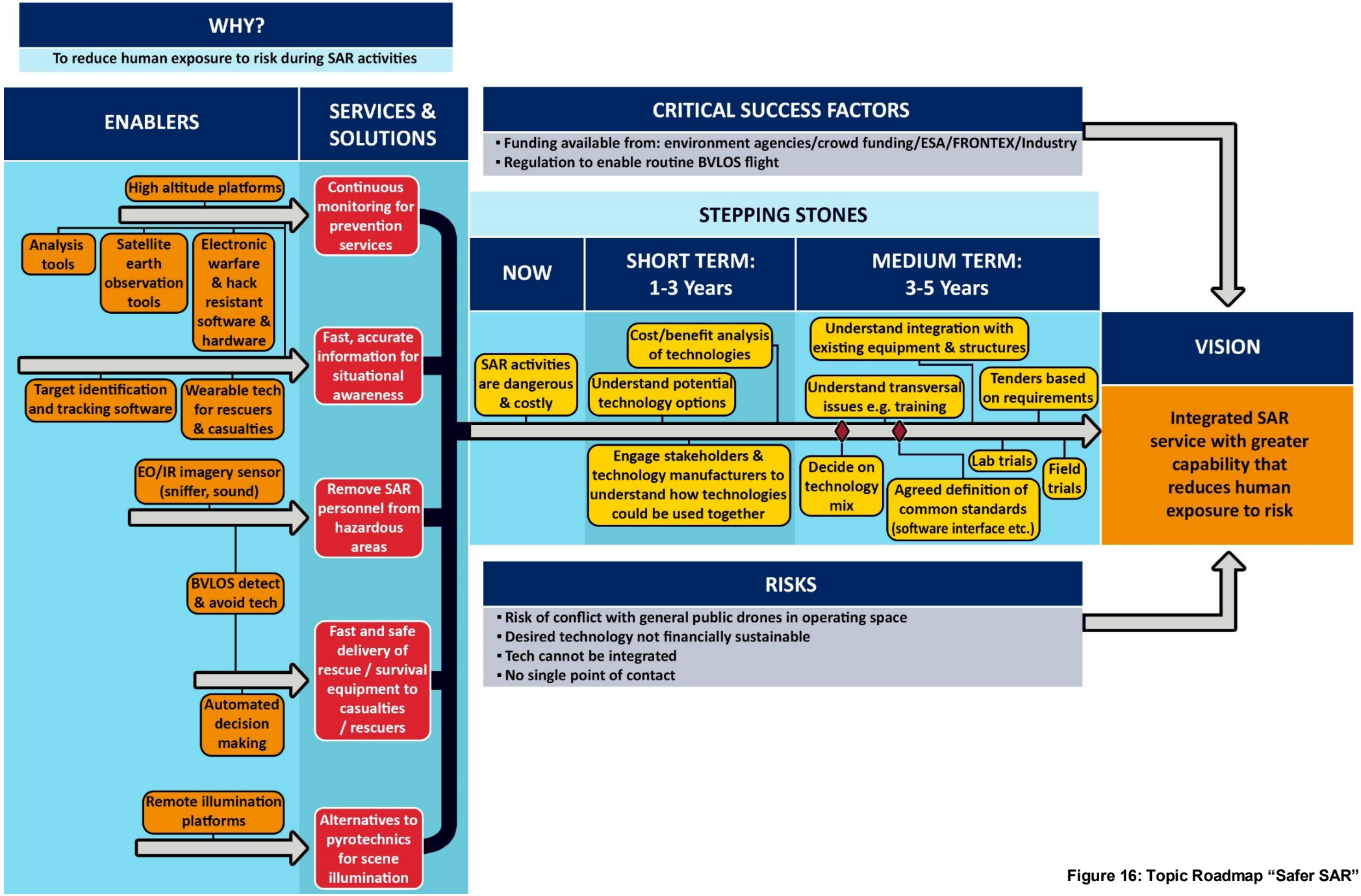


Figure 16: Topic Roadmap "Safer SAR"

Topic Roadmap: Human Centred Design Approach

Putting the human at the centre of the process through which a capability is developed is vitally important for project success and the reduction of costs that may be associated with late changes in project scope.

This roadmap describes how the UK SAR community can move towards a system that is designed with end users in mind and therefore, a capability that can fulfil its potential and is safe, effective, and efficient. The human is placed at the centre of the capability development process by the adoption of Human Centred Design principles and Human Factors Integration methodologies. The former (HCD) ensures the holistic collection of needs and the latter (HFI) ensures these needs are translated into requirements that are realised in the subsequent system.

It has been demonstrated across a variety of projects that HFI is a worthwhile endeavour from a cost perspective. In a recent analysis conducted by DSTL, for every pound (£) invested in HFI, fourteen pounds are saved over the lifetime of the project. As cost is a driver for many projects, this return on investment is a significant lever that could be used to further rationalise investment.

It is recommended that a HFI plan be developed on the outset of this programme which outlines all the various HF integration processes that should be undertaken at each stage of the programme.

Using the Design Reference Missions developed by the UK SAR community, subject matter experts and end users will be invited to provide their insights on how the capability can be leveraged to deliver the desired effect. Delivered through a workshop format, these CONOPs will then form the capability requirements against which COTS can be down-selected or a bespoke system be developed.

An early human factors analysis will provide UK SAR with an understanding of all the HFI domains that the capability will affect, and ensure that the community has all the necessary manpower, personnel, skills and competencies etc. to support the capability. A critical component of this work will involve the development of the system safety case and associated issue logs which can also be used to inform requirements.

Taking into account the continual emergence of technologies that have different modalities / interaction devices, it is important that we continuously assess the impact these changes may have on how end users expect to interact with technology and how it affects factors such as decision making and machine-human communication.

TOPIC ROADMAP: ENSURING SUCCESS FOR SAR THIRD DIMENSION OPERATIONS THROUGH A HUMAN CENTRED APPROACH

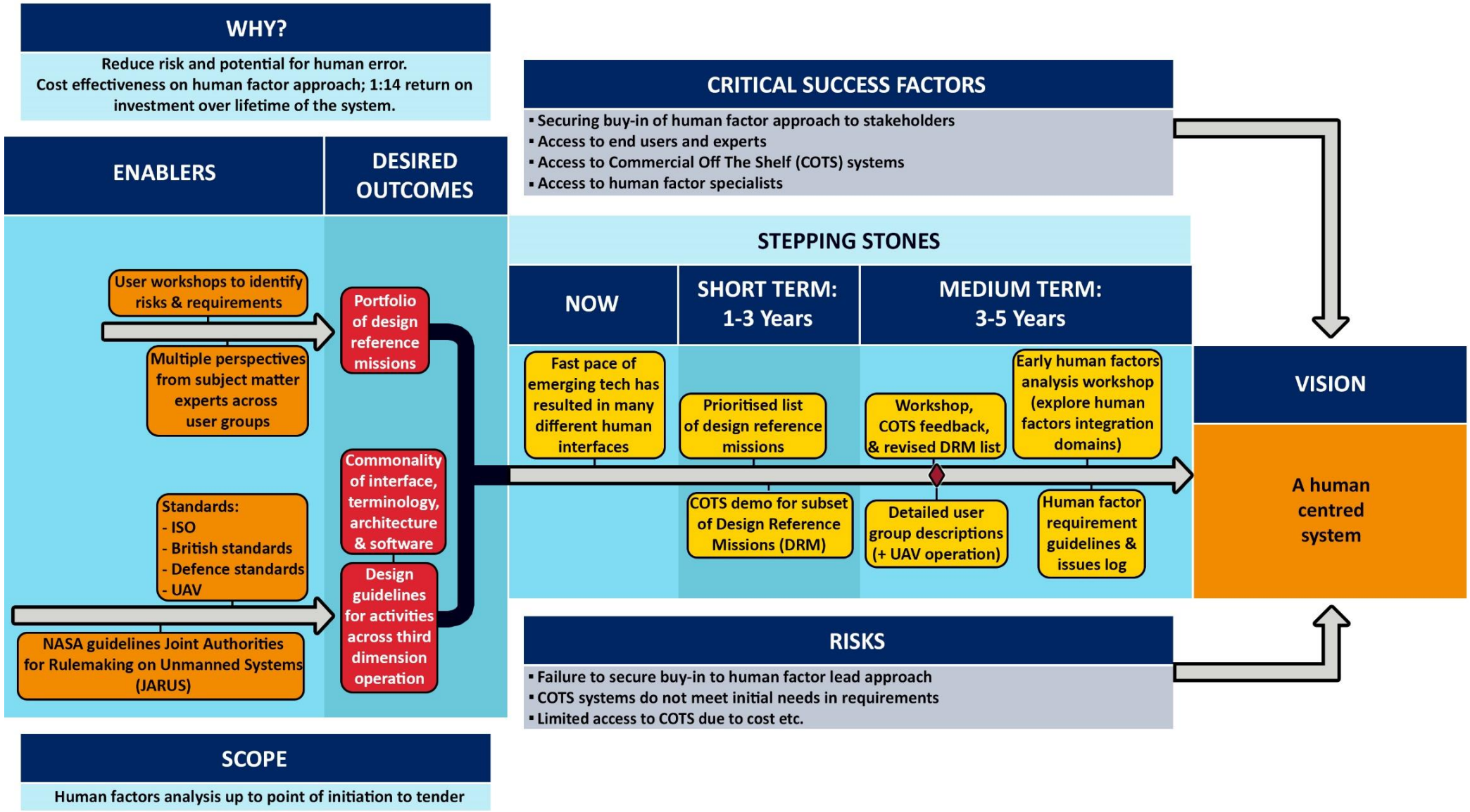


Figure 17: Topic Roadmap "Ensuring success for SAR third dimension operations through a human centred approach"

CHAPTER SIX
DISCUSSION

The roadmapping exercise brought much needed coherence to the UK SAR Community's strategy to exploit UAS technology through the development of a common vision.

Through exploring the landscape, a better understanding has been reached on how external Trends and Drivers are predicted to interact with emerging technologies from across industry sectors. Technical Subject Matter Experts provided awareness of the maturity of relevant technologies and enabled participants to cut through the hype and identify what state-of the art will look like in the short, medium and long term. End Users were also informed of what the possibilities are, thus avoiding the pitfalls of just wanting a faster, better version of what they already have (e.g., faster horse vs. a motor vehicle analogy).

The topic roadmaps formed a tangible output of the workshop as these identify stepping stones needed to be taken towards routine integration of unmanned aerial capability into lifesaving operations.
The level of interest from Organisations that saw a benefit in participating in the event is a clear indication that there is appetite among SAR Operators to avoid bespoke systems being developed by different operators/agencies in isolation. It was unfortunate that UK Border Force were unable to attend at the last minute. However, they endorsed the exercise and expressed a willingness to engage further with the output and follow on activities. A noticeable gap was from onshore operators.

In the lead-up to the event, effort was made to engage with Mountain Rescue, Lowland Rescue and the Police, however this did not result in any participation from these organisations. It is hoped that onshore operators will be encouraged by the outputs of the roadmapping to engage with requirement gathering and demonstration opportunities.

In conducting work like that described herein, it important to be aware of the risk of unintentional biases. Whilst the contributors were mindful of the potential of Satellite and future HALE platforms to provide future capability, detailed contribution to this topic area was light. Similarly, the short-term benefits of implementing simpler solutions such as aerostats / heli-kites was not explored in depth as they are relatively well-defined solutions, but the benefit of these as localised sensor platforms for increased height of eye is recognised (as shown in road map for exploitation, Figure 20).

Positive engagement from Industry during the roadmapping exercise showed a desire from industry to work with End Users as early as possible in the design phase to develop products that are fit for purpose. There was also a cautionary note from industry representatives that the pace of technology development has the potential to outrun the SAR Community's ability to define requirements quickly. If these are not available in a timely manner, opportunities may be lost resulting in higher costs later as systems have to be adapted for purpose.

CHAPTER SEVEN

NEXT STEPS FOR THE RNLI

The positive engagement received from the organisations that participated in the roadmapping exercise has endorsed the collaborative approach in the development of a future vision and a desire to reduce the risk of duplication of effort across agencies. The RNLI is well placed as a trusted third party to continue to facilitate the coordination of SAR agencies towards the wider exploitation of unmanned aerial systems. However, it is important to note that the RNLI would be acting on behalf of UK SAR and are agnostic about who would actually be responsible for the deployment of any future unmanned capability.

Three follow-on pieces of work have been identified from the roadmapping exercise with the aim of understanding the implications on the RNLI through the following activities:

- Development of Design Reference missions to compare system capabilities
- Technology demo programme to inform the organisation of the potential performance characteristics of system solutions
- Operational analysis (including cost-benefit) of impact of introduction of airborne platforms on asset distribution and future concept of operations.

Figure 18 shows the interaction between RNLI activities and the UK Strategic level activities. Requirements developed from RNLI activity will feed into the Search and Rescue Pathfinder programme, led by the Maritime and Coastguard Agency. Where there are also some synergies with the 'Blue Light' Pathfinder programme, outputs will be shared between the Pathfinders to avoid duplication.

Phil Hanson
Aviation Technical Assurance Manager
Maritime & Coastguard Agency

"From an HM Coastguard perspective, the road mapping workshop was a fantastic opportunity to contribute to development of the potential future SAR capabilities in the UK. The work undertaken will allow HMCG to use the high levels of experience of the attendees to help shape the Maritime Pathfinder project to ensure that the requirements of each project are complementary and will deliver benefit for the RNLI, industry as well as HMCG. HMCG are grateful to the RNLI for the opportunity to contribute"

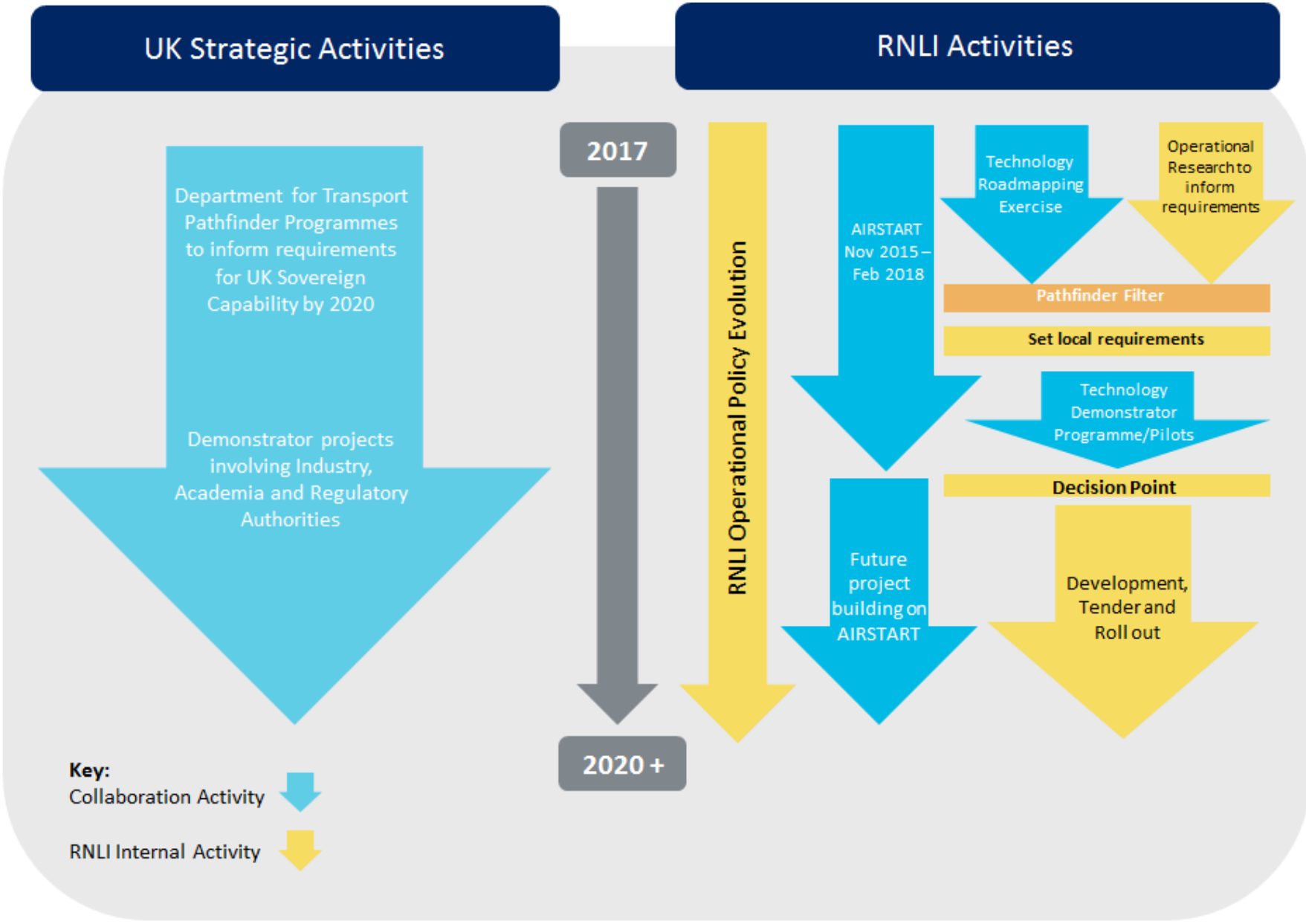


Figure 18: RNLI strategy for exploitation of UAS

CHAPTER EIGHT
IMPLICATIONS FOR UK SAR

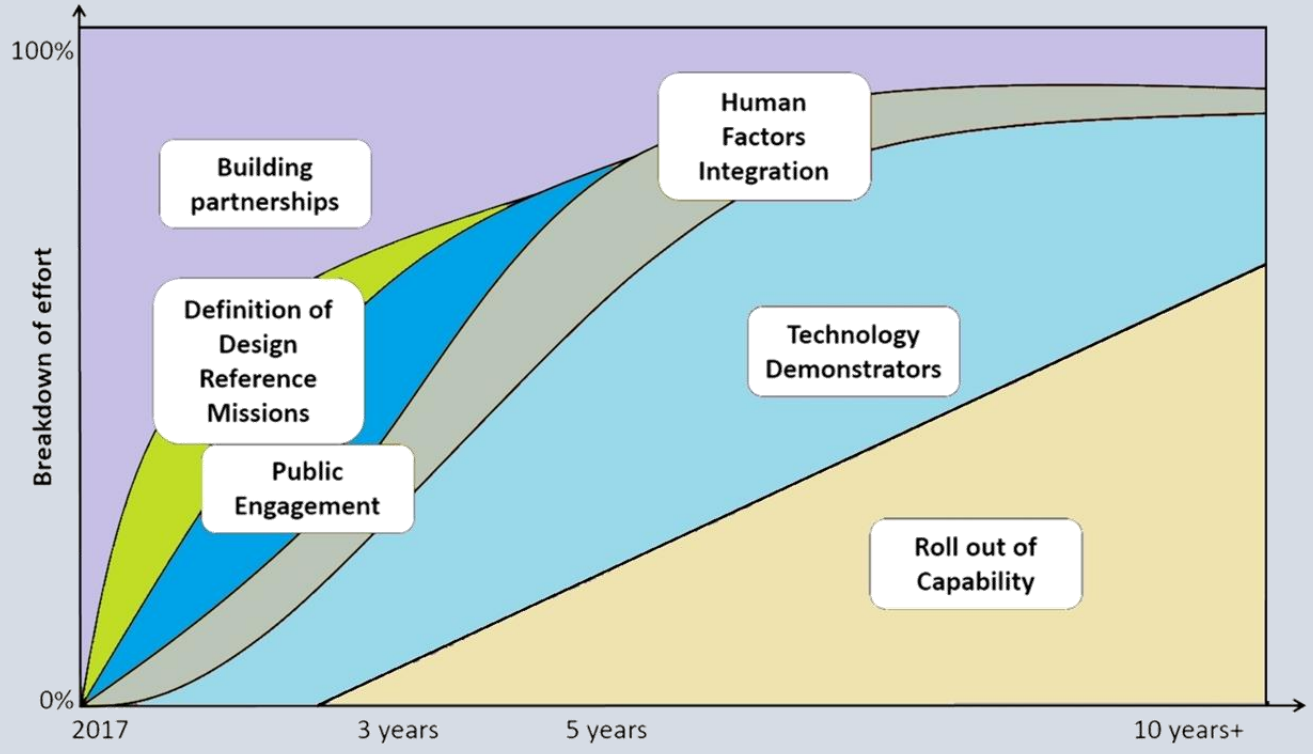
Based on the activities and timescales identified in the topic roadmaps, Figure 19 shows the predicted spread of effort (time and resources) needed from UK SAR and industry partners over the next 10 years to establish UAS capability as a routine part of SAR. The initial efforts are focused on building the collaborations and partnerships to establish coherent requirements via definition of Design Reference Missions that can be used to compare characteristics of existing capability against technology demonstrators.

Public engagement activity is concentrated in the short term – out to three years by which time roll-out of localised capability is realised and examples of 'drones for good' demonstrated in the SAR environment.

Human centred design is a critical enabler for successful implementation of all the systems and services identified in the roadmaps. This is reflected in the effort starting now and growing as systems are developed. As systems mature and are integrated with existing capability, human factors integration becomes focused on the scaling up of operating models.

Technology demonstration effort grows from mid-2017 to account for~ 50% of effort in the medium term. Roll out of localised, tactical small platform capability could start within two years, with demonstration and development of more strategic capability from satellite and long range, high endurance systems in the medium to long term.

Figure 19: Focus of effort required to reach the vision



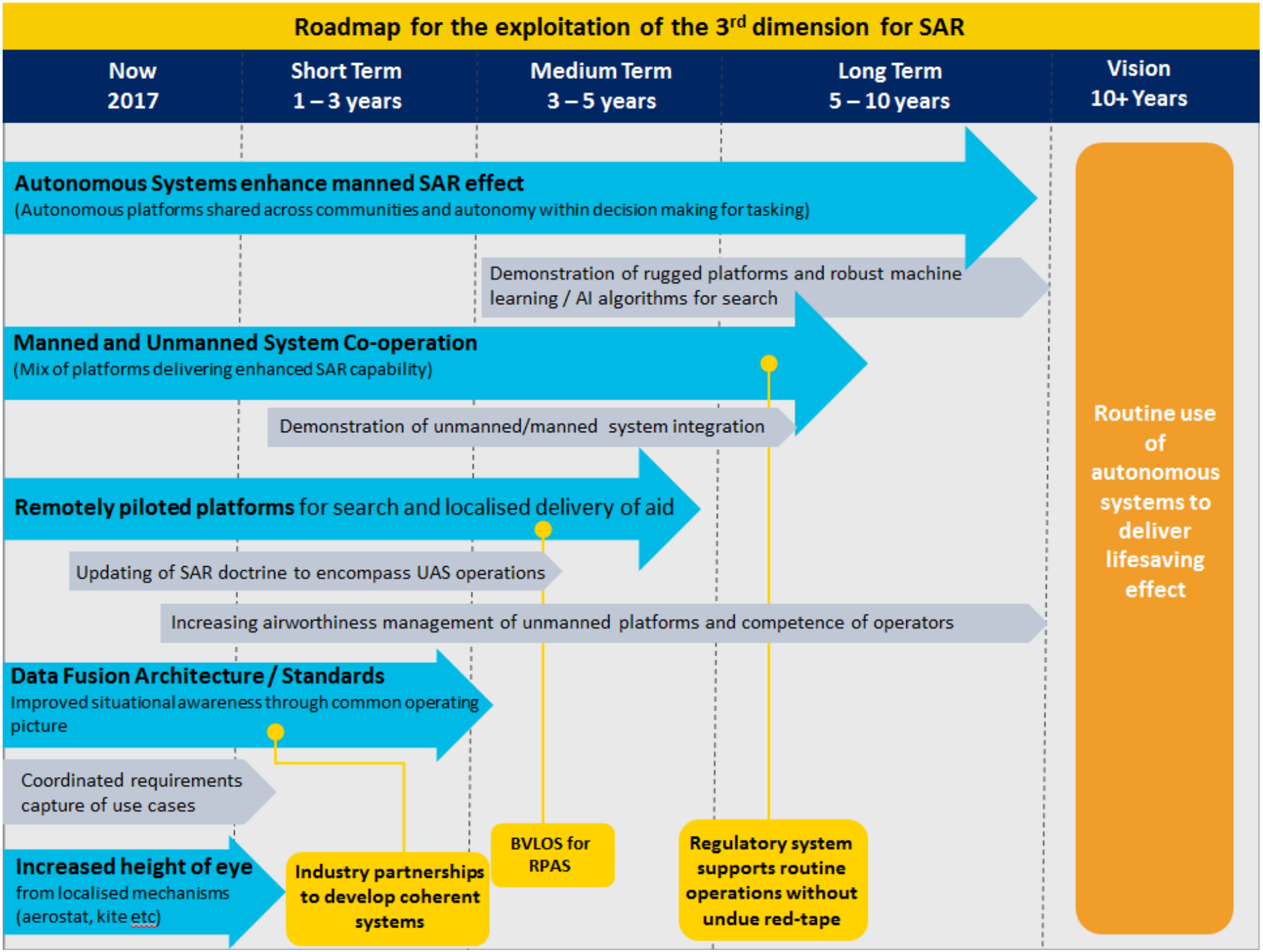


Figure 20: Roadmap for the exploitation of the 3rd dimension for SAR

The roadmap in Figure 20 shows the timeline of progression towards exploitation of autonomous systems for SAR. The arrowhead for each Service/Solution shows when it is anticipated that exploitation of that system could be realised.

In the short term, localised platforms such as masts, aerostats etc. could demonstrate the benefit of using sensors (optical, thermal, and hyper-spectral) at an increased height of eye; and sharing this data with relevant SAR partners. In parallel, use cases need to be developed into coordinated requirements from the SAR Community.

Development of standards for sharing and integrating data feeds from different sources is key to providing improved situational awareness in the short term. Successful formation of Industry partnerships to develop coherent systems was identified as a milestone towards achieving a common operating picture for SAR.

Increased airworthiness management of platforms and competence of operators is shown to develop alongside technology to enable safe flight beyond visual line of sight in the medium term. This opens up the greater possibility for remote delivery of aid and search applications.

The integration of unmanned systems with crewed assets is essential for safe and efficient operations and the critical enabler for this in the medium to long term is a regulatory system that supports routine unmanned operations without undue red-tape.

Looking ahead to the vision, autonomy in decision making and algorithms for search is seen as the area that needs to mature the most to demonstrate safe and robust solutions before benefit can be realised by the SAR community.

CHAPTER NINE
CONCLUSIONS

A coherent joint vision was identified for a future where unmanned systems are routinely used to compliment crewed assets for delivery of Search and Rescue.

The SAR community has an opportunity to collaborate and present joint requirements to industry; this would avoid bespoke systems being developed in isolation and allow cost savings to be realised from commonality of components, operating approaches and reduced development time for systems.

The message from industry was clear; that their preference is to work with end users to inform their product design. However, if requirements are not defined in a timely manner, industry will push ahead with their 'best educated guess' of requirements to get products to market ahead of competitors. The risk to the SAR community in this scenario is higher costs for capability that is not optimised for the environment; and operating models that we require.

Would you like to get involved?

We would love to hear your thoughts on this report, as well as ideas for future workshops!

Get in touch:

innovation@rnli.org.uk

Photo submissions of our delegates:
Potential applications of UAV in SAR

ANNEX

Workshop structure and details

25 subject matter experts from representing Operators, Industry, Regulators and Academia participated in the workshop.

Facilitators

Dr. Clemens Chaskel	IfM ECS
Hannah Nobbs	RNLI
Tim Robertson	RNLI
Dr. Will Roberts	RNLI

Delegates

Andy Horler	Lockheed Martin
Andy Keane	University of Southampton
Anthony Miller	UAV Evolution
Arthur Richards	Bristol Robotics Lab
Ayan Ghosh*	EE
Ben Thomas	RNLI
Dan Hook	ASV Global
Daniel Jones	DfT
Fredrik Falkman	SSRS
Gemma Alcock	Skybound Innovations
Gerry Newell	Human Factors Specialist
Jonathan Webber	Callen-Lenz
Matthew Bennett	Freedom Sensors
Nigel Birdsall	Bluebear Systems
Noz King	MCA
Oliver Mallinson	RNLI
Paul Thomas	CAA
Peter Hughes	Insitu
Phil Hanson	MCA
Piera di Vito	ESA
Richard Glyn-Jones	Sentient
Stephen Way	Frazer-Nash
Sue Wolfe	ARPAS
Tristam Newey	MCA

*insights provided by email.

Approach

The workshop was broken down into two days. Activities on Day 1 focused on understanding the strategic landscape for the future of exploiting the 3rd dimension for SAR. From this, high priority themes were identified that where considered in more detail in topic roadmaps on Day 2.

Day 1: Understanding the strategic landscape

Factors that make up the landscape were broken down into the following areas:

- *Trends and Drivers:* Why do we want to change what we are doing now? What external factors will influence the landscape (Political, Environmental, Social, Technological, Legal and Economic)?
- *Services and Solutions:* What services do we need? What solutions can the RNLI offer?
- *Technologies:* How to we realise the services and solutions that are needed?
- *Enablers and Barriers:* What factors will help or hinder us achieving the desired future state?

Day 2: Detailed Topic Roadmaps

Ten topics that were identified as areas of interest were explored in more detail during Day 2 of the workshop using the IfM's Topic Roadmapping approach.

Key topics:

- Topics that directly benefit SAR future capability:
- Situational Awareness and Common Operating Picture
- Search
- Delivering Effect Remotely
- Preventative SAR

Enabling topics that allow the above key topics to be realised:

- Safer & more efficient SAR
- Multi-Use Business Model
- Integration of UAS into SAR Operations
- Human Factors Design Approach
- Public Engagement
- Cyber Security

Roadmapping theoretical background

Roadmaps provide a structured visualization of particular strategic aspects. They are used to support strategic planning across a broad spectrum of applications. A common roadmap layout, or architecture, will contain two axes. There is a horizontal, time-based axis; often encompassing the past, short-, medium- and long-term, as well as the vision. The vertical axis usually pertains to perspectives, or dimensions, relevant to the focal point of the roadmap; often represented as horizontal layers, forming a matrix across the time dimension.

A roadmap allows the integration and alignment of several different perspectives across a broad time range. In this way, the development of currently developing, or short-term, underpinning science and technology to support long-term market trends and drivers can be explored. As a result of this flexibility, roadmaps can be applied at different levels – international, industry, company and product-specific roadmaps have been produced (Phaal et al., 2004; Phaal & Muller, 2009). They can also be applied in a hierarchy – with industry-level trends and drivers cascading down through organizational objectives into specific products and technology features and parameters – a great benefit to the RNLI, who interfaces with manufacturers and policy makers, recreational users and professional mariners.

Roadmapping processes typically follow a pattern of divergence, convergence and synthesis (Phaal et al., 2010). Brainstorming and scenario planning are divergent activities which benefit the process by encouraging open and innovative thinking by participants.

In contrast, convergence requires some discipline to focus the attention onto the most important issues identified in the divergent activity. Thus, workshops tend to employ a divergent-convergent cycle of activities, culminating in a synthesis stage where summarising and sense-making help create a coherent set of roadmaps (Phaal et al., 2010).

The activity of recognising and acting on the impact of trends is a vital element of competitive strategy (Aguilar, 1967). As technology becomes increasing complex and has a larger impact on manufacturing firms, technology intelligence is vital for firms to remain competitive. Kerr et al. (2006) found that technology intelligence “provides an organization with the capability to capture and deliver information in order to develop an awareness of technology threats and opportunities.”

The roadmapping process employs similar techniques for scanning for trends in the external environment (Phaal et al., 2012). This information is typically drawn from the expert participants in the early stages of the workshop, however one mechanism to enhance the information generated and captured is to pre-populate the roadmap prior to the workshop. Approaches for this include a) participants can be requested to prepare in advance, or b) external researchers can be commissioned to identify important trends and drivers.

Behind the scenes: Roadmapping at the RNLI

Defining customer requirements

Prior to the initiation of the roadmapping exercise and engagement of external subject matter experts, the RNLI Innovation Team worked with internal stakeholders to clearly define their problems and what constituted success for this programme of work. Through a series of one to one meetings and after engagement with senior decision makers, a formal requirement document was developed.

Developing the approach

Working with the IfM ECS, the Innovation Team developed a roadmap framework / template that would facilitate the capture of insights and 'technical intelligence' provided by the external community and RNLI expert practitioners. Modifying templates already used by IfM ECS, it was decided to collect information and insights along the following themes:

- Trends and drivers
- Products, services and solutions
- Technologies and systems
- Capabilities, enablers & barriers

Identifying contributors

To develop the roadmap, it was essential that the RNLI gathered insights from a broad audience that was engaged with our purpose, understood the intent behind the roadmapping exercise and was sufficiently forward thinking to stretch our understanding of the current and emerging landscape of the 3rd Dimension for SAR. The Innovation Team hence sought a balanced mix of participants from government, industry and academia to contribute. Essential to the success of this exercise was the participation of each member without any commercial or political bias – a sentiment that was bought in to by all.

Pre-Work: Collating insights

Prior to the roadmapping workshop, key insights on the selected topic areas were gathered by the project team from the workshop participants. A blank roadmap template was sent to participants, soliciting comments and insights relating to trends and drivers etc. and when the participant thought they would impact the landscape (short, medium, longer term). Over a two-week period, over 1,500 insights from 20+ of the participants were collated.

Roadmapping literacy

Whilst most participants were aware of the roadmapping concept, few had actually participated in a roadmapping exercise. To ensure that everyone was one the same level and was able themselves to leverage most value from the exercise, the IfM ECS facilitator held two webinars. During these on-line exercises, participants were given an overview of the methodology, its origins and its utility to organisations like the RNLI. Participants were then talked through the Pre-Work and invited into a Q&A on the methodology. Both RNLI and external parties took advantage of this learning opportunity.

Rationalising and clustering insights

On receipt of the pre-work from workshop participants, the IfM ECS clustered and de-duplicated insights, rationalising all the information provided to yield a roadmap that could subsequently be taken into the workshop as a 'starter for ten' that could subsequently be built upon. Included in this activity was an analysis of the frequency and prevalence of certain insights and their emergence over time.

Roadmapping workshop

The main roadmapping activity was carried out over two days. 25 delegates from a range of backgrounds attended, reaching from academia, equipment manufacturers to the RNLI, the Maritime and Coastguard Agency and stakeholders from communication infrastructure providers and the aerospace & defence sector.

During the first day, the delegates worked together to understand and map the unmanned air system for SAR landscape as a whole. On the second day, the group was split into focus groups to work on detailed roadmaps of topics that were of particular importance to the group, before again engaging the wider audience in a discussion on these topics.

Synthesis

Following the roadmapping event, all outputs were codified and recorded by the RNLI project team, with guidance from IfM ECS. Synthesis included audio recordings and physical content (i.e. topic roadmaps from the workshop). The project team then synthesised the insights into a more concise set of individual roadmaps, simplifying and interpreting as they went. Throughout this intensive exercise, care was taken not to lose meaning from the content.

Visualisation

Roadmaps are visual devices for communicating to decision makers how a vision may be achieved, what needs to be done to get there, and what factors are enabling, blocking and driving the achievement of that vision. It is essential therefore, that the roadmap is designed in such a way that these things are effectively communicated and the desired result is achieved. The visualisations were produced by the project team in collaboration with Skybound Innovations.

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RNLI
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Dorset
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