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Space Assets for Demining Assistance

Dr. Michiel Kruijff
SERCO/ESA, Noordwijk, The Netherlands, michiel.kruijff@esa.int
Dr. Daniel Eriksson
Geneva International Center for Humanitarian Demining, Geneva, Switzerland, d.eriksson@gichd.org
Dr. Thomas Bouvet
European Space Agency (ESA), Noordwijk, The Netherlands, thomas.bouvet@esa.int
Mr. Alexander Griffiths
Swiss Foundation for Mine Action (FSD), Geneva, Switzerland, geneva@fsd.ch
Mr. Matthew Craig
Cranfield University, United Kingdom, m.p.s.craig@cranfield.ac.uk
Prof. Hichem Sahli
Vrije Universiteit Brussel, Brussels, Belgium, hichem.sahli@etro.vub.ac.be
Mr. Fernando Valcarce González-Rosón
INSA S.A., Madrid, Spain, fvalcarce@insa.org
Mr. Philippe Willekens
International Astronautical Federation, Paris, France, philippe.willekens@iafastro.org
Prof. Amnon Ginati
European Space Agency (ESA), Noordwijk, The Netherlands, amnon.ginati@esa.int

Populations emerging from armed conflicts often remain threatened by landmines and Explosive Remnants of War. The international Mine Action community is concerned with the relief of this threat. The Space Assets for Demining Assistance (SADA) undertaking is a set of projects that aims at developing new services to improve the socio-economic impact of mine action activities, primarily focused on the release of land thought to be contaminated, a process described as Land Release. SADA was originally initiated by the International Astronautical Federation (IAF). It is now being implemented under the Integrated Applications Promotion (IAP) programme of the European Space Agency (ESA).

Land Release in Mine Action is the process whereby the demining community identifies, surveys and prioritizes suspected hazardous areas for more detailed investigation, which eventually results in the clearance of landmines and other explosives, thereby releasing land to the local population. SADA has a broad scope, covering activities such as planning (risk and impact analysis, prioritization, resource management), field operations and reporting.

SADA services are developed in two phases: feasibility studies followed by demonstration projects. Three parallel feasibility studies are currently ongoing. They aim at defining an integrated set of space enabled services to support the Land Release process in Mine Action, and at analysing their added value, viability and sustainability. The needs of the Mine Action sector have been assessed and the potential contribution of space assets has been identified. Support services are now being designed. To test their fieldability, proofs of concept involving mine action end users in various operational field settings are also under preparation by each of the study team. The economic viability will then be assessed.

Whenever relevant and cost effective, SADA aims at integrating Earth Observation data, GNSS navigation and SatCom technologies with existing Mine Action tools and procedures, as well as with novel aerial survey technologies. Such conformity with existing user processes, as well as available budgets and appropriateness of technology based solutions given the field level operational setting are important conditions for success. The studies have already demonstrated that Earth Observation data, Satellite Communication and Navigation indeed provide added value in Mine Action activities. Such added value for example includes the benefits of easy and sustained access to Earth Observation data that can satisfy the ubiquitous needs for general purpose mapping, as well as the value of data fusion algorithms which can be applied to relevant datasets to quantify risks and socio-economic impact for prioritization and planning purposes in order to justify land release. The environment of a hazardous area can also be characterized to support the land release process including detailed survey and clearance. Satellite Communication can help to provide relevant data to remote locations and in some cases can help to integrate field data and reporting with national or international databases. Finally, Satellite Navigation can support more precise non-technical surveys as well as aerial observation with small planes or hand-launched UAV's.

To ensure the activity is genuinely user driven, the Geneva International Centre for Humanitarian Demining (GICHD) plays an important role as ESA's external advisor. ESA is furthermore supported by a representative field operator, the Swiss Foundation of Mine Action (FSD), providing ESA with a direct connection to the field level end users. Specifically FSD has provided a shared user needs baseline to the three study teams. To ensure solutions meet with end user requirements, the study teams themselves include Mine Action representatives and interact closely with their pre-existing and newly established contacts within the Mine Action community.

I. SADA AND ESA'S INTEGRATED APPLICATIONS PROGRAMME

Space Assets for Demining Assistance is a set of projects of the Integrated Applications Program (IAP) of the European Space Agency (ESA).

ESA's Agenda 2011 contains a key objective: "*Development and Promotion of integrated applications (space & non-space) and integration of security in the European Space Policy. New concepts, new capabilities and a new culture have to be developed in order to respond to a multitude of needs from users who are not yet familiar with space systems*." Responding to this objective are the Integrated Applications Programme (IAP), also known as ESA's ARTES 20 element (user-driven applications), as well as the ARTES 3-4 Telecommunications Applications element (product-driven applications). These elements are dedicated to development, implementation and pilot operations, utilising not only Telecommunications satellites, but also combining the use of different types of space assets, including Earth Observation and Navigation, as well as Human Spaceflight technologies.

The overall goal of the IAP program is the *"the development of operational services for a wide range of users through the combination of different systems"*. The goal is to incubate sustainable services for the benefit of society that obtain their added value from the innovative integration of existing terrestrial technologies with space assets, such as Telecommunications, Earth Observation, Navigation, and Human Spaceflight technologies. "*Sustainable*" means here: triggered by, responsive to and sustained by real user demand, while taking into account financial (e.g. commercial) and non-financial (e.g. environmental, legal, adoptability) constraints. The provision of commercial *services* (rather than of mere products) is seen as a key outcome - one that offers flexibility and increases sustainability of demand, supply, and indirectly, up the value chain, also of space assets. In this way, "our satellites help to do better the daily work of society".

Such services are to be incubated through two steps or levels of ESA IAP activities:

1. Basic activities, which aim at generating, assessing and studying ideas for projects. Feasibility Studies provide the preparatory framework to identify, analyse and define new potentially sustainable activities.

2. Demonstration activities which aim at development and demonstration of the novel services identified in the first element, until an operational maturity is achieved that is satisfactory to the users.

IAP activities cover a wide range of themes, including Health, Transport, Energy, Environment, Development, Safety, Agriculture and Fisheries.

In January of 2011, within the theme of Safety, three parallel Feasibility Studies regarding Space Assets for Demining Assistance have been initiated that intend to conclude by early 2012. One or more Demonstration Projects are then likely to follow to demonstrate the SADA services to the key mine action end users.

II. DEMINING

II.1 Challenges for Mine Action Land Release

Landmines and Explosive Remnants of War (ERW) still kill or maim civilians every day, even long after conflicts are over. For landmines alone, an estimated 110 million live units have been scattered in about 70 countries since 1960[1]. At the current rate of clearance of about 500.000 mines per year[2] and assuming no additional mines are laid from now on, it could still take hundreds of years to find and clear all the landmines around the world. Each year the remaining units claim between 15,000 and 20,000 new victims. In addition, landmines and ERW dramatically hinder the recovery of economies wounded by a conflict, because resources located within areas such as arable land, infrastructure and water suspected of mine contamination cannot be exploited.

The 1997 Mine Ban Treaty aims to provide momentum to demining activities and targets clearance of mine affected areas within 10 years after ratification. Landmine Monitor estimates that as of August 2009 there may be left, worldwide, less than 3,000 km2 of contaminated land, in which the vast majority of the remaining mines are concentrated[2]. However, of all the land that has been subjected to meticulous landmine clearance activities, in retrospect only about 2.5-10% was found to be contaminated - the remainder could as well have been released without clearance effort[3]. This fact represents a major and unnecessary cost factor, considering that the average cost of clearance is around $\$1/m^2$, whereas well-informed land release (without such clearance efforts) costs only $\$0.02$-$\$0.05/m^2$, see [4].

Such statistical analysis results in a need for the Mine Action community to focus their efforts in three ways:

1. *Target with priority those minefields that are most threatening and costly to society.*
2. *Avoid the unnecessary deployment of clearance activities in non-contaminated areas.*
3. *Reduce the cost of detection and clearance per unit of land area.*

With the help of new methodologies and technologies it should thus be feasible to resolve most of the (historic) landmine problem within the next few decades.

At the same time, the problem of ERW remains and even increases, in particular considering submunitions. Cluster bombs spread out many highly explosive units (the submunitions) over the surface of targeted areas, where a significant percentage does not detonate as intended (ranging from 4-50%) and thus presents a real danger to the population. The first major use of cluster bombs was in South East Asia in the 60s and 70s. Widespread usage continues to this day. As an example of the scale of the problem, in Laos alone up to 27 million submunitions remain[5].

The combined issue of landmines and ERW calls for cost-effective innovations that improve the land release process and thus increase the socio-economic benefit of often scarce mine action activities.

II.2 Current practice of mine action land release

The process of Mine Action land release involves a significant amount of preparatory activities before mines and ERW can be located and actually cleared. Although the cost per unit of land area for these preparations is much lower than the cost for clearance, the volume of land to be investigated in the preparatory stages is generally much larger. A recommended methodology for land release is presented in Figure 7 [3,4,6,7]. This methodology serves as a guide for the remainder of this document, although it should be noted that it is not the only methodology and has not been implemented universally. See Figure 1 for a representation of definitions used in this listing. Figure 3 shows an example of a real world map of the areas explained here.

a. The first step is the **General Assessment** (General Mine Action Assessment or Land Impact Survey). A high level analysis is made of risk factors and socio-economic interests to identify and prioritize the Suspected Hazardous Areas (**SHA**) for investigation.
b. Typically a **Non-Technical Survey** will then be conducted which can consist of a range of information sources including local interviews, incident reports, and analysis of historical conflict information. In some cases, accurate and reliable records of mine locations exist which results in a significant reduction in the amount of time to clear. More typically however only a very limited amount of suspected land can then be cancelled so that it can be used by local communities or for national and local development, whilst the remainder will then be demarcated as a Confirmed Hazardous Area (**CHA**) for subsequent Technical Survey and clearance.
c. Through a **Technical Survey** most of the CHA will be investigated further in order to identify what areas require clearance, and which can be released without full mine clearance. This is usually conducted through lane clearance involving mine detectors and probing, visual inspection and other on-site activities. Patterns and other evidence is used to determine the Defined Hazardous Area (**DHA**) which subsequently requires clearance.
d. Only at this time the **close-in mine and ERW detection and clearance** will take place, in the DHA. Clearance is conducted, detected contamination is removed, and the land is thereby ready for hand over to impacted communities for effective use.

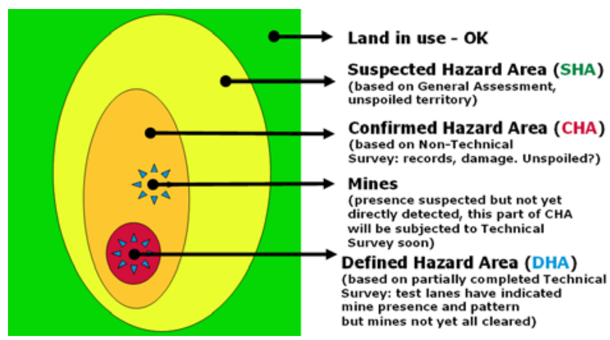

Figure 1. Schematic definitions for hazard classification in Land Release.

The final step of demining, involving mine detection and clearance remains a painstakingly slow process. Humanitarian demining requires a near perfect detection (a near 100% mine detection probability) in the sense that mines shall not be missed. So-called false negatives can not be accepted. For this reason, detection equipment must be tuned to respond even to low signals, which often causes the equipment to provide a false positive reading for objects and disturbances in the ground that are neither mines nor ERW. In fact, such false alarms routinely outnumber the actual detections of mines by hundreds to one and thus become primary drivers of the clearance cost.

Trained animals such as dogs (and rats) currently provide the most sensitive chemical tracing of mines and produce few false alarms. Though, in optimal ground, dogs detect mines in no more than about 95% of the cases. Such detection probability is therefore only sufficient for confirmation purposes. For some environments demining machines can be very suitable[8], though they are often costly to acquire, to deploy, and to maintain.

The primary method for obtaining sufficient detection probability of buried explosive ordinance is still a manual based process that involves close inspection of the soil by trained personnel equipped with individual prodders and metal detectors. On average a trained deminer processes a mere 35-50 m^2 per day.

The development of novel mine and ERW detection technologies is hampered by the multi-faceted nature of the problem. Mines, ERW and minefields can appear in a wide range of scenarios with varied characteristics including the type of terrain, type and conditions of the soil, type of minefield, type of mine or ERW, range of depth and orientation, and varied obstacles that impact upon the effective detection such as vegetation or metal contamination.

A large variety of innovative technologies for mine and ERW close-in detection are effective in laboratory conditions, e.g. Ground Penetrating Radar (GPR, Figure 2) and acoustic sensing. Each method has its own strengths and weaknesses. For example, GPR in combination with a metal detector for example works well for shallow mines in dry soil[9], whereas mine detection dogs do better in wet soil, but not on steep slopes, etc. However so far, no single innovative technology has provided an adequate solution covering the full range of contamination and field conditions[8,10,11].

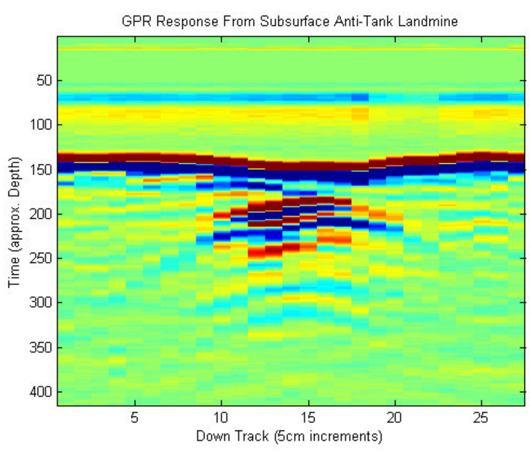

Figure 2. Ground Penetrating Radar result example for an anti-tank mine.

Stand-off detection systems have also been studied recently for the purpose of individual mine and ERW detection. Although it would be highly desirable to reliably detect individual buried landmines from a remote standpoint, a solution is considered by mine action experts and the technology sector not to be available in the near term.

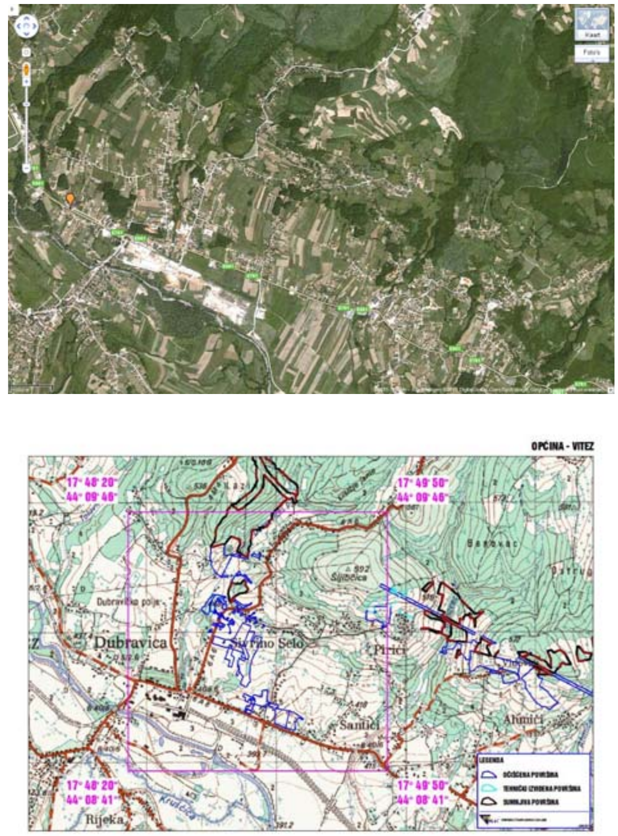

Figure 3. Example of maps indicating SHA (red/black), CHA (blue) and cleared areas (light blue) vs. Google Earth image, courtesy of BHMAC.

II.2 User segments

Within the complex arena of stakeholders (Figure 4)[12], users of humanitarian (non-military) land release services based on space assets can be divided over principally three segments: decision makers, operators and donors.

1. **Decision makers** in this context are the entities that decide on prioritization of regions for Non Technical Survey, Technical Survey and clearance. They may be National Mine Action Authorities (NMAA), or in their absence, UN bodies such as UNMAS or government authorities supported by UNDP. Such decision makers need socio-economic impact information to make reliable estimates of the mine/ERW problem in their country, as well as an overview of the resources and difficulties involved in implementing mine action activities. At the national operational level, National Mine Action Centers (NMAC), often assisted by NGO’s or

UNMAS, coordinate the regional activities of demining organizations.

2. The regional **field operators** may be NGO's, military, commercial demining companies, typically employing local people trained for mine action activities. They need services to support operational planning and the demining operations themselves.
3. **Donors** are unlikely to be direct customers of SADA services, but are influential, as they will want to have access to a reliable indicator of the progress of mine action activities and receive quantitative information to support investment decisions in particular equipments or methodologies. They often have particular constraints with respect to the activities they fund, e.g. limited to a particular region or type of activity (e.g. mine education, landmine clearance).

In some cases, demining activities are initiated by corporations with localized commercial exploitation needs, e.g. to provide access to resources or infrastructure. Such **corporate users** can be seen as a fourth group of users within the scope of SADA.

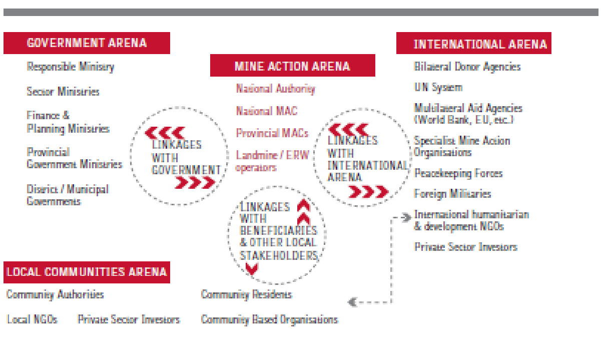

Figure 4. Mine Action stakeholders, source: GICHD.org

II.3 Users' drivers and constraints

Mine Action users have clear needs and will accept innovations only if certain conditions are met (see also [4,13]), including:

- **The cost/benefit ratio is a major driver.** Funding for research and investment is limited as budgets are often earmarked for specific identified mine or ERW clearance work. Donors may however be more willing to invest if non technical effectiveness can be traced clearly in a quantified, visual and objective manner. The cost/benefit ratio at a given budget can further be improved at the level of the General Assessment by maximizing the socio-economic impact of a given land release effort. For this, strategic planning tools are necessary, which could be based on an integration of remote sensing data with existing databases. At the level of the Non-Technical Survey, significant costs could be saved by more efficient collection and integration of field level data. Improvement of the Technical Survey which distinguishes contaminated zones from mine/ERW-free zones could lead to a more accurate focus for scarce mine action clearance resources and could thus reduce the amount of unnecessary fieldwork. According to a 2004 study on landmine clearing over 15 countries an average of 97.5% of cleared land proved to be uncontaminated[3].

- **Innovations (technologies and methods) should be easily deployable and generate immediate increase in land release efficiency.** To this end they should be easy to use and in line with existing procedures. In fact any deviation would require significant additional implementation and training costs. This necessary "fieldability" of the system also includes also includes ease of use by operators, appropriate technology and interoperability with existing tools (such as the Information Management System for Mine Action, IMSMA, as detailed below[14]).

- **Overall detection performance of the technology is imperative**. Performance does not necessarily have to be obtained by a single detection technology. A toolbox of innovative and complementary detection technologies could be utilized, each with its own strengths under certain known scenarios, surface and weather conditions. A reliable method would then be required to characterize the scenario present at a given time and for a given geographical area, and thus select which of the available detection technologies should be deployed for optimal performance and cost.
  Performance parameters include sensitivity or detection probability (high value reduces the risk of releasing land that still contains mines or ERW) and the Positive Predictive Value (PPV) of the detection or discriminatory ability (with high value, few false alarms are generated).

- **Assistance to access, demarcate and navigate the zone to be cleared**, for more automated reporting, data sharing, for secure communication and data relay in remote areas, etc.

II.4 Recent developments

Maturing technologies and procedures could make a real positive impact to Mine Action land release activities if properly integrated into an efficient seamless service and methodology.

Advances have been made on the organizational level. In 2009, standards for Land Release processes have been added to the International Mine Action Standards (IMAS 08.20-08.22)[15,16]. These standards also serve to avoid inflation of the mine problem, and discourage the assignment of large amounts of resources to areas that have only low impact or a weak case for being contaminated.

The Geneva International Center for Humanitarian Demining (GICHD)[3] has developed and is promoting the widespread use of the Information Management System for Mine Action (IMSMA), originally released in 1999[17]. It is supported by a definition of best practices and standards for usage and marking of maps in Mine Action related Geospatial Information Systems (GIS). IMSMA includes a database with an intuitive graphical user interface (GUI) and GIS that can be used for planning, prioritizing, managing, reporting and mapping the results of Mine Action surveys and clearance activities. It is in use in more than 80% of mine action programmes around the world.

Stand-off detection, even if it does not provide sufficient overall detection performance to proceed directly to clearance activities can provide important complementary inputs to Technical Survey and can assist with the discrimination between mine/ERW-free and contaminated field based locations significantly reducing land area for close-in detection[18,19] (Figure 6).

The so-called SMART approach (Space and Airborne Mined Area Reduction Tools[20]) and related approaches such as the Decision Support System (DSS)[21,22], the Airborne Minefield Area Reduction (ARC)[23,24] and its spin-off "General Aerial Survey"[10] have been recognized to offer support to the efforts in area prioritization and hazard confirmation.

These methodologies focus on indicators of landmine presence. It must be stressed that they are not a mine detection technology, but rather a methodology that integrates a variety of geographical data. They output maps of danger, based on indicators of mine presence, obtained from contextual information, such as spaceborne and airborne data, combined with Mine Action information, such as accidents, mine field records, historical events. Tests on actual minefields have demonstrated that these approaches provide a good indication of mine presence and produces a useful recommendation for demining action. In addition, they are able to reliably identify some of the suspected contaminated areas as uncontaminated, based on evidence of human activities. Although costs are relatively high and specific expertise is required to support the interpretation of the acquired stand-off data, the DSS has been successfully operated on extended yet remote (so-called "Class-III") areas in Croatia that otherwise could not be cost-effectively released.

Such approaches that fuse space, airborne and geo-spatial data are able to deal with innovative inputs, as they aggregate all available evidence (indicative of mine absence or mine presence) into a consolidated index of mine presence or absence. There is thus a flexible potential for enhancements, such as inclusion of remote sensing technologies and data for detection of evidence of mine laying activity or submunitions damage but also for a more direct detection of (individual) mines and ERW.

Evidence for mine laying or bombing activity may be gathered by analysis of historical data sets. Regular comparison of optical or radiometric imagery in conflict areas may reveal mine fields or locations as soon as the mines/ERW are deployed, based e.g. on temporary changes in the soil and vegetation structure. This comparative analysis may also be applied to past conflicts. To this end, an inventory of relevant available spaceborne/airborne imagery may provide support.

Preliminary testing and service operations in Israel and Angola have suggested that plants and microbes growing in a contaminated field could be subject for identification from satellite hyperspectral imagery[25,26]. Such a technology could provide valuable complementary information for a range of mine action programs that face particular difficulties that conventional methods can only handle at very high cost (**Figure 5**).

There are various concepts for direct mine and ERW detection, which are not yet available at operational level, that could be enhanced by stand-off technologies, such as:

- Objects on the surface such as submunitions can be detected in various ways including optical and multispectral sensing.
- Objects just under the surface could be detected through day-night effects unique to explosives locations by diurnal comparison of stand-off detection data, using infrared sensing or radiometry[27].
- Various airborne detection systems for individual buried mines or ERW are under development, which make use of a combination of ground penetrating radar and InSAR-type algorithms.
- A proposed detection method for individual mines or ERW uses biomarkers like microbes emitting fluorescent light when in contact with explosives which can be excited by laser light (close-in technology) for detection from a stand-off location[28].
- In some cases, aerial magnetic field sensing can be used e.g. to detect patterns of metal anti-tank mines.
- Change detection could be suitable for delineation of potential mine or ERW areas.

The stand-off detection methods that detect individual mines and ERW, even if limited in detection probability, typically promise relatively low false alarm rates. Thus, they could help to recognize patterns in mine-laying or submunitions clustering and to define tighter boundaries for resource intensive close-in detection and clearance work. The extent to which such a reduction of close-in detection effort is accepted is a matter of risk management and will generally depend on an individual national authority.

Other developments cover field and reporting activities of all types that may well be streamlined by user friendly satellite navigation and communication applications. For example, current navigation methodologies for the demarcation of mine/ERW fields are based on bearing and distance measurements, but could be improved by augmented satellite navigation technologies providing the required accuracy to allow operating under vegetation canopy or other challenging environments.

Sustainability relevance		Afghanistan	Bosnia	Cambodia	Colombia	Congo	Cyprus	Ecuador	Egypt	Iraq	Laos	Mozambique	Sudan	Zambia
1	Cluster ammunition	4	0	4	0	0	0	0	0	4	4	0	0	0
2	Commercial operations	4	4	0	0	0	0	0	0	4	0	0	4	0
3	Large area	4	4	3	3	0	0	0	0	4	0	2	0	4
4	Vegetation (TBC)	1	3	3	3	0	0	3	0	1	0	2	0	0
5	Difficult access	4	3	4	0	0	0	3	0	4	0	2	0	0
6	Disturbed minefields	0	4	0	4	0	0	0	0	4	0	2	0	0
	Other	0	0	3	0	2	0	0	2	0	0	0	2	0

Figure 5. Potential countries suitable for hyperspectral detection of vegetation contaminated with traces of explosives, following user interest expression in ESA survey. High interest = 1, very high interest = 4. The scoring is a combined value, relative not only to other countries but also to other (not-listed) services. The "sustainability relevance" ranking of the selection criteria is based on the level of interest as expressed by the mine action community as a whole.

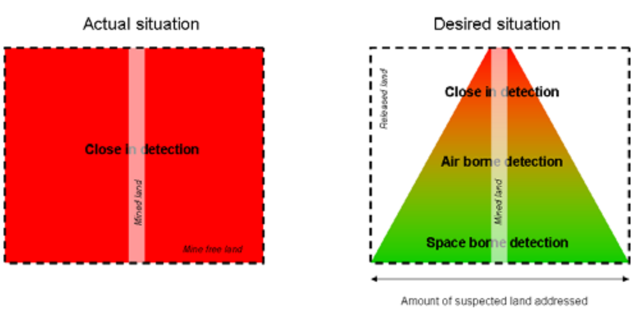

Figure 6. Targeted benefits of land release by stand-off detection

II.3 Space assets for mine action

A non-exhaustive list of potential services relying on space assets is described here referring also to the methodology presented in Figure 7.

At the level of General Assessment, Earth observation can provide beneficial support. The starting point for General Assessment could be existing map material and data such as digital terrain models and land use maps. If these are not considered to be sufficient, additional new satellite imagery could complete the mapping information. EO data of suspected contaminated areas could be used to indicate risk factors of mine presence (such as strategic position) as well as socio-economic impact (e.g. fertility of the land). By integrating demographic and topographic maps, areas of high density of human activity, heavily used access pathways, living areas and grounds used for sports and other activities could be identified. This information could be combined to produce impact maps for decision makers to define priority zones and to plan activities for maximum impact within a given budget and timeframe (Service 1 in Figure 7).

For the Non-Technical Survey, GIS and Earth Observation data combined with GNSS could be used to georeference reports and identify and mark suspect locations (Service 2 in Figure 7).

For the Technical Survey, various space assets could contribute to the detection of minefields and ERW-contaminated areas. These tasks will then require less field work (the stand-off detection perhaps fitting better the non-intrusive definition of Non-Technical Survey).

Minefields may have a different signature from space/air over various frequencies compared to surrounding fields or the same fields before mining (Service 3 in Figure 7). Specifically, if historical data is present or alternatively captured at the beginning of conflicts, identifying such changes can be a viable approach. Spaceborne Earth Observation data could help increase the overall performance level of the aerial and close-in detection by generating recommendations for sensing methods and timing which depend heavily on the scenario including topography, weather, vegetation state, as well as existing knowledge. Soil moisture data and vegetation density dynamics derived from multi-spectral infrared/optical sensors could provide insight into vegetation levels and seasonal patterns. Combined with surface slope mapping and weather forecasts, the best technology selection and the best times in the year to operate the stand-off or close-in detection could be determined. In particular planning of demining activities could be improved and costs could be better estimated (Service 4 in Figure 7).

Satellite navigation provides the means to optimize the routing of sensing aircraft/UAV over zones of investigation, reducing overlap and time to get full coverage, and thereby the cost of fuel, manpower and maintenance. Low-cost 2D/3D mapping technologies using hand-launched UAV's are currently available[29,30].

Precise navigation is also required to geo-reference remote sensing data to the observed position on the ground (Service 5 in Figure 7).

Satellite navigation technology could be used to unambiguously and efficiently fence off danger zones and mark released areas, and reduce costly unnecessary safety margins due to inaccurate information, common as a result of conventional distance-bearing methods. Future Galileo GPS navigation signals and Satellite Based Augmentation Systems such as EGNOS can be combined to improve not only accuracy but also to significantly improve signal integrity and availability in case of obstruction, such as under vegetation canopy or in mountain valleys[31] (Service 7 in Figure 7). Terrestrial relative positioning systems based on satellite navigation allow position accuracy well below one meter (differential GPS), and if required, centimetre level (RTK network). The latter will be much more costly to install, but may have additional benefits such as for agriculture, thus requiring careful trade-off. Such precision may be relevant for site marking and guidance purposes (Service 8 in Figure 7).

Communication is obviously critical in Mine Action, and is required between national and often remote regional mine action centers, as well as for national and international coordination (such as involving operators' main offices, UN bodies, GICHD for IMSMA software, and international conferences). In addition, the SADA services themselves may require reliable communication links for delivery of maps.

Mine Action communications are generally not considered highly time-critical and given the absence, degradation, or break-down of terrestrial infrastructure, solutions are almost always available (incl. satellite phone back-up, manual file transfer, or sheer patience). However, Satellite Communication may well have a more constructive role to play. Broadband Satellite Communication (e.g. BGAN or possibly VSAT based) can enable cost-efficient and reliable provision of EO services (map delivery) as previously mentioned to remote mine action centers. These communication infrastructures could then also be used for reliable communication, reporting, conferencing, as well as software updates. A more coherent and reliable communication solution which reduces delays and interruptions is likely to improve adherence to reporting procedures, which will benefit of traceability and quality management of mine action activities (Service 6 in Figure 7).

Finally, following the release of contaminated land, donors can be provided with impact maps overlaid with land release data, base on integration of GIS technology with Satellite Navigation and Earth Observation data as an insightful means of quantifying progress (Service 9 in Figure 7).

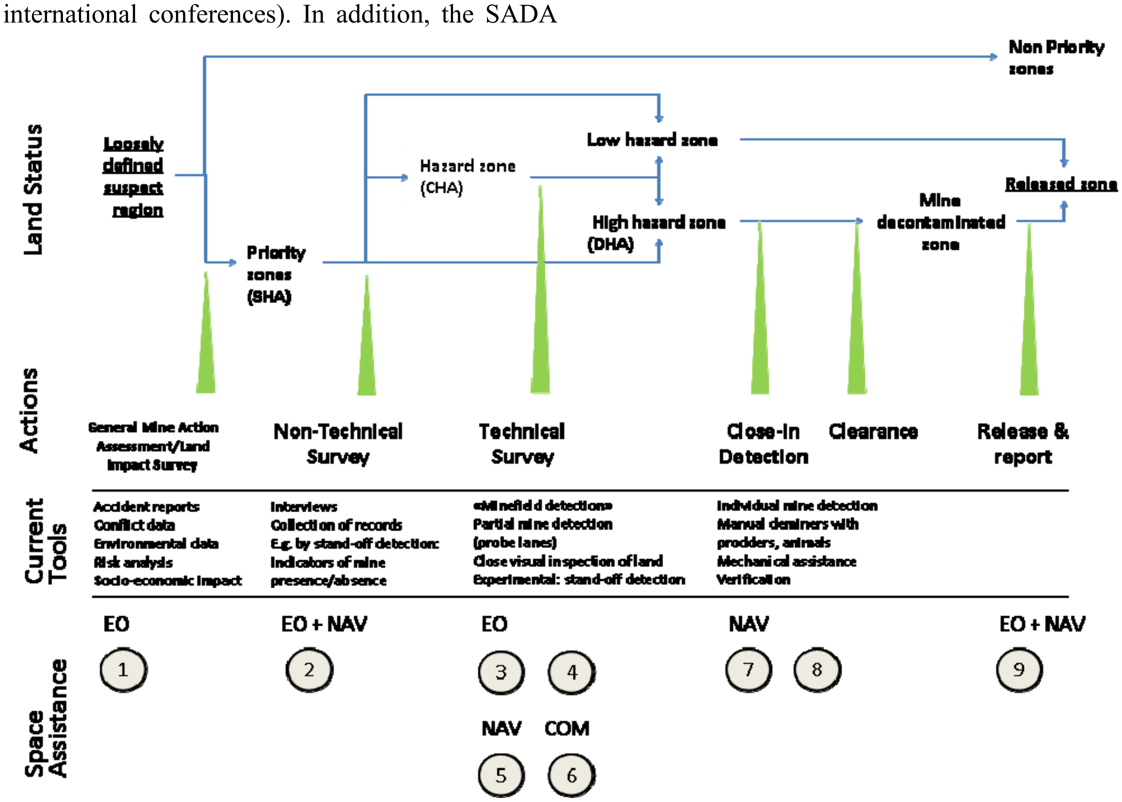

Figure 7. Recommended process for Land Release. Potential for Space Assets is indicated.

II.4 The SADA Project

In order to maximize impact on socio-economic development of landmine and ERW impacted countries, the SADA Feasibility Studies aim to assess the feasibility and viability of innovative integration of existing terrestrial methodologies and technologies with space enabled services to improve and optimize the planning, preparation, efficiency and impact of land release activities in Mine Action in order to answer the following questions:

- What added value can space assets provide in:
  - increasing the socio-economic benefit of mine action as a result of better prioritization,
  - improving non-technical survey work,
  - confirming and defining hazardous areas (incl. minefield detection) as well as land cancellation and release,
  - enhancing the mine and ERW detection effort by using stand-off imaging to better plan the use of close-in technologies,
  - supporting field work (incl. clearance)
  - reporting of results and interfacing with databases.
- How can this added value be improved by integration of space enabled technologies with existing accepted procedures, systems and services?
- What should an integrated system and service look like taking into account the current modus operandi, interests, constraints and concerns of mine action stakeholders?
- What sustainable services can be realistically provided considering currently available space assets, as well as technical and commercial viability?
- Can a service provider(s) and user(s) be identified to take part in and co-fund a potential follow-on demonstration project?
- Which are the capability gaps that cannot be overcome with existing assets?

II.5 The Study Teams

Three consortia, each with complementary capabilities and user representation, are undertaking the SADA Feasibility Studies in parallel. They are led respectively by Infoterra (UK), Radiolabs (IT) and INSA (E). ESA is supported in its management of these activities by the GICHD, which acts as a neutral observer. GICHD and the participating users and consortia are further introduced below.

GICHD

The GICHD is an international non-profit organization based in Switzerland which is staffed by mine action experts. The GICHD, in partnership with others, strives to provide capacity development support, undertake applied research, and develop standards, aimed at increasing the performance and professionalism of mine action. In addition, the GICHD supports the implementation of relevant instruments of international law, and manages the development and review of the IMAS standards on behalf of UNMAS to guide the planning, implementation and management of mine action programmes [15].

The GICHD role in SADA is to ensure the relevance and applicability of the results from the feasibility studies, and to coordinate the studies with other mine action developments. For this reason GICHD has supported the project definition, participates in project reviews, and has hosted a SADA discussion with the consortia and user community during the 14th International Meeting of National Mine Action Programme Directors and UN Advisors (March 2011).

SADA leverages on GICHD experience and ongoing research. For example, in August 2011, GICHD hosted a training workshop for the SADA consortia in order to allow them to develop effective interfaces between SADA services and IMSMA[17].

Figure 8. SADA-IMSMA interface workshop at GICHD

User involvement

Beyond the support of GICHD, the Mine Action community is broadly represented in SADA:

- Both during and following the 14th International Meeting of National Mine Action Programme

Directors and UN Advisors in Geneva in early 2011, ESA and the SADA consortia have extensively discussed mine action needs and concerns with a broad range of users. Part of the results which covering 37 contributors have been documented through an ESA User Survey (see Section III.1).

- Each of the consortia has representative Mine Action users (NGO's, commercial operators, national authorities) directly involved in their study teams.
- The consortia have held their own workshops and conducted individual user surveys to collect and analyse mine action user needs and concerns.
- Each consortium will hold a proof of concept supported by a relevant Mine Action programme (including Afghanistan, Bosnia i Herzegovina, and Chile).
- ESA is supported in particular by a representative field operator, the Swiss Foundation of Mine Action (FSD), an NGO providing ESA and individual consortia with a direct connection to mine action field operators. FSD is active in Lao, Tajikistan, Lebanon, Afghanistan, and Armenia, and provides ESA with user needs and feedback based on the work of the consortia, as well as hosting a field visit to Tajikistan for the benefit of the SADA consortia.

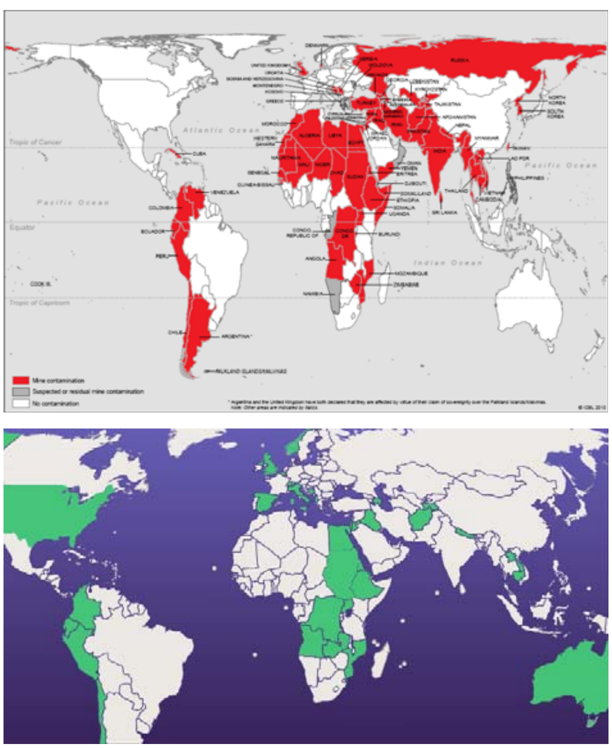

Figure 9. Mine affected countries vs. nations so far that have representatives participating in SADA.

Figure 9 provides an overview of the mine affected countries as well as of the contributors to the SADA projects so far.

<u>Consortia</u>

- **Infoterra (UK)**. The Infoterra consortium consisting also of Cranfield Mine Action (Cranfield University) and BAE Systems provides a unique combination of experience of space enabled solutions to benefit a wide range of sectors, extensive expertise on state of the art sensor technology, and extensive experience of the mine action sector through experience of close collaboration with over 30 mine action programmes as well as national and international non governmental organisations, national authorities and mine action centres, as well as commercial mine action companies. The consortium benefits greatly from the direct involvement of MAG, and MineTech International, as well as representative members of the national mine action programmes in Sudan and Afghanistan (two of the largest mine action programmes in the world).

- **Radiolabs (IT)**, an international consortium with Università di Roma "Sapienza" (IT), MEEO (IT), Vrije Universiteit Brussel (B), Aurensis (E), and domain experts GTD – Sistemas de Informacion (E), Agenzia Industrie Difesa (IT) and Appalti Bonifiche Costruzione (IT). This "SAFEDEM" consortium is active in all the phases of the development lifecycle with expertise covering Earth observation and mapping, unmanned aerial vehicles, satellite navigation, (satellite) communications, Mine Action applications based on IT (Information Management, Geographic Information Systems, Data Mining, Geospatial and Risk Analysis), artificial intelligence and data processing.

- **INSA (E)**, an all-Spanish consortium with Hispasat (E) and domain expert EXPAL. The consortium combines expertise in remote sensing products provision and operational systems development, satellite communications provision, knowledge of the military mine action market and mine land release expertise.

III. SADA INTERMEDIATE RESULTS AND STATUS

III.1 User Needs

Shared User Baseline

The FSD "Shared User Baseline" produced for the the SADA studies details the peculiarities of demining and land release in Mine Action. Following a conflict, risks, benefits and hence Mine Action priorities typically shift significantly over time (Figure 11). Threats within a post-conflict area often occur in a mix of various scenarios, in terms of contamination (patterned, non-patterned minefields, and/or ERW), as well as physical environment (such as mountains, deserts, grass, bush etc.). As no single "silver bullet" solution exists covering all scenarios, it is not easy to define a specialized service that meets the majority of user needs even within a single country or mine action programme.

Services must therefore be flexible, generic and be capable of integrating different inputs. The use of IMSMA is one of the few common factors within the sector, and general purpose mapping has been identified as the most common need. FSD also confirms there is a general need for access to reliable information that does not require field based access to suspected hazardous areas, and for methodology and technology to better reduce (cancel or release) non-affected land, and to provide better reports/rationale to donors. There is *no* need for better clearance (destruction) technology as current approaches are widely considered to be satisfactory.

Solutions should therefore be robust and based on incremental innovation, be built on or interoperable with existing tools & systems (such as with VHF/HF/mobile phone, (D)GPS etc), and be operable and maintainable by local staff who require minimal infrastructure and training.

Requirements analysis has indicated that costs should be in keeping with individual donor priorities and budgets, and there should not be an expectation that cost for a service/solution will be borne by the host country. As most high impact, easy access and well-documented minefields have been cleared, funding for Mine Action is currently levelling off despite the abundance of remaining ERW and more challenging minefields. The priority is to integrate mine action into other types of development, such as traditional development, reconstruction, recovery, peace and security. To obtain and maintain donor support, results should be quantifiable not only in terms of socioeconomic benefit, but also in relation to development goals (such as agriculture & food security, infrastructure, health, and stabilisation of populations).

ESA User Survey

The ESA User Survey was a crude survey among the mine action community to map the level of interest in services and improvements that may be supported by space assets. The survey covered 37 respondents from 20 mine affected countries and areas, as well as various UN and NGO representatives. An overview of intermediate results (30 respondents, 15 affected countries/areas) are presented in Figure 15.

Participants were asked to judge an item as "Relevant" if it relates to:

- a core activity for their organisation,
- an issue of high urgency or high impact for the region,
- a difficult issue to deal with, i.e. many resources would be required on a daily basis to deal with this issue to your full satisfaction,
- a large scale issue, in terms of area affected or total level of contamination, or
- a chronic issue.

Most services listed were considered to be highly relevant. In order to identify confirmation bias or bias by selectivity of the respondents (**Figure 14**), a rescaling was performed, from which confirmation bias was found not to be too significant however the relatively large fraction of information management professionals was noted to have raised the relative relevance of technical and information related services.

Consortia Users

The consortia took these initial ESA survey results into account in subsequent discussions with mine action end users, through web surveys, interviews and workshops. Subsequent identified consortia needs were largely in line with the ESA survey results, though have been more specific in the detail of needs, requirements, constraints and success criteria in order to define commercially viable services.

Top relevance	
19	Planning & prioritization of mine action activities
19	Land release to enable access and repopulation
17	Information to maximise release of land with high socio-economic impact
16	Information to improve land release without technical survey and more objective SHA delimitation
16	Land release to enable agriculture/farming
15	Collecting & combining indicators of presence or absence of contamination
15	Detailed hazard mapping (from historical data, field reports, feature recognition, geographical, climatic indicators, ordnance footprint estimation)
Not so relevant	
13	Improved capacity building and risk education in absence of on-site experts
11	Land release for other purposes (tourism, Art. 5 obligation, ...)
11	Demining assistance for terrain with difficult access or challenging conditions for dogs and machines
09	Assessing impact of floods, landslides and other events that affect mine/ERW distribution

Table 1. Relevant services with potential space asset contribution as ranked by the survey respondents (ad hoc scorings)

III.2 SADA High Level Concepts and Next Steps

Infoterra Consortium

The Infoterra consortium has identified a wide range of user needs and requirements relative to the provision of space enabled solutions (Figure 10). The key challenge that they have identified relates to the cost effectiveness of such solutions, a factor that has limited the adoption of previous similar technologies at both a national and global level. The consortium has defined two fundamental yet flexible, and integrated services:

(i) *Decision Support Service*
Based primarily on Earth Observation data processing chain, prepared to take in other geographical data sources.

(ii) *Field Support Service*
With the intention to support field teams with mapping, communication, navigation and GIS functionalities.

The consortium is working closely with their representative end users in the preparation of a proof of concept which will trial their proposed two-pronged space enabled integrated service in order to directly benefit the mine action sector, and look forward to further refining their proposed service based on important feedback from end users.

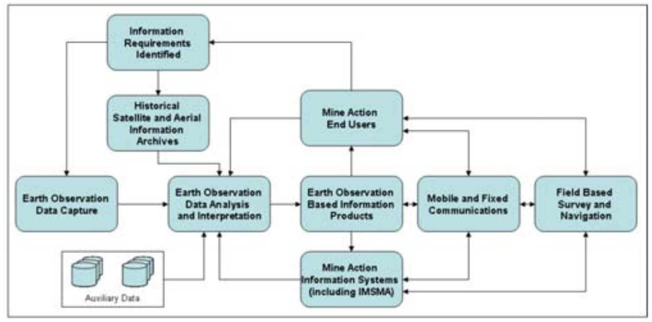

Figure 10. Infoterra high level functional SADA concept.

Radiolabs Consortium (SAFEDEM)

Having finalised the user requirements and needs phase, the focus of the Radiolabs Consortium "SAFEDEM" concept is *Data Acquisition* and *Data Exploitation*, aiming to provide operational and decision support for Mine Action Land Release process, mainly in the context the activities of the General Assessment, the Non-Technical Survey and the Technical Survey, described in Section II.2. New tools will be designed in the form of added-value services and/or plug-in applications to IMSMA with direct interfacing to it. The SAFEDEM concept combines thus two elements:

1. SAFEDEM Data Acquisition Services

- A pyramidal remote sensing imagery acquisition (historical Low to high resolution Satellite images, combined with very High unmanned aerial vehicle (UAV) images),
- Thematic maps production, including but not limited to, topographic, land cover, land cover change, Digital Terrain Models (DTM), soil, mine and mine field indicators maps, and GIS layers production,
- Field Mobile Service at the intersection of GIS, Navigation systems and Telecommunications implementing the so-called 'telegeoprocessing' technologies such as: Integration of mobile computing, data acquisition and GIS (Mobile geoprocessing)

2. SAFEDEM Data Exploitation Services
These services are Geospatial Decision Support and advanced on-line reporting, analytics, dashboard – Business Intelligence Services Platform, to sustain the workflow of the above considered Mine Action Activities, in particular the following survey process phases:
(i) planning and preparation,
(ii) data collection,
(iii) analysis, integration and interpretation,
(iv) risk and impact assessment, and
reporting & dissemination.

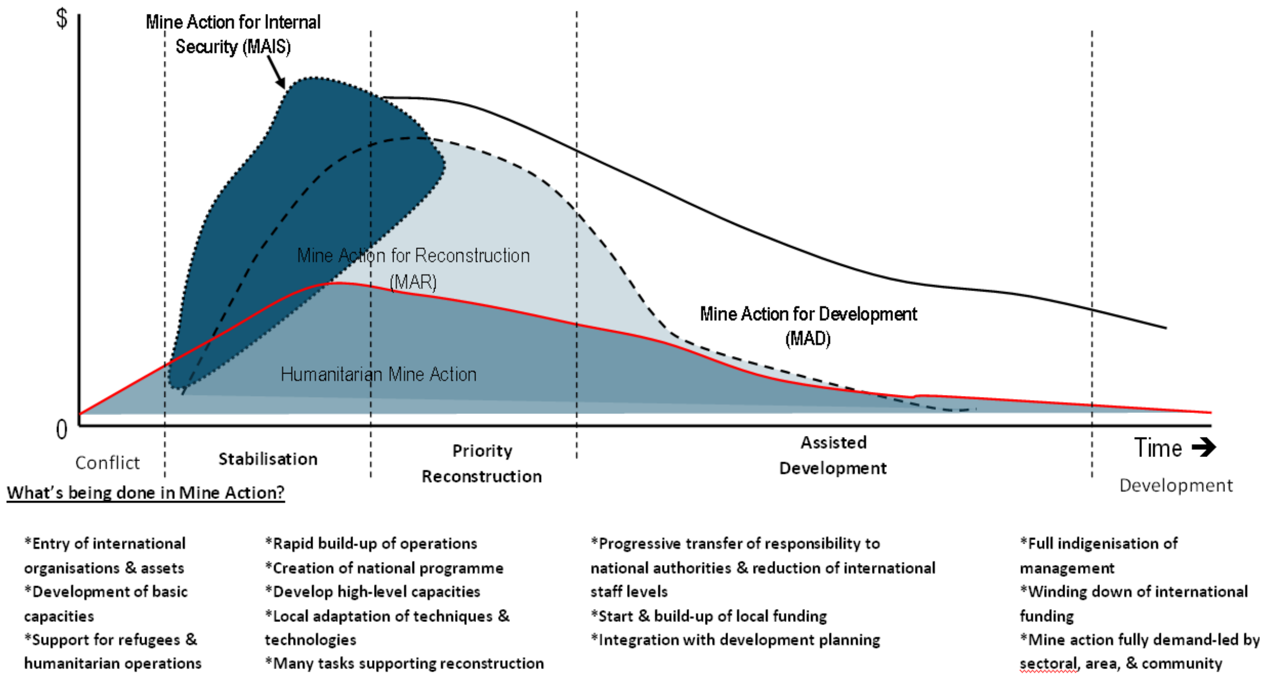

Figure 11. Mine Action Life Cycle

The SAFEDEM consortium is closely collaborating with the Bosnia and Herzegovina Mine Action Center, the Tajikistan Mine Action Centre-United Nations Development Programme, and the United Nations Mine Action Office in Sudan, in refining user requirements and user needs assessment with respect to operational scenarios and stakeholders characterisation, and scenarios proposal for the proof of concept. The overall planes of the proof of concept are to demonstrate the feasibility of SAFEDEM Services to assess their usefulness in the above process phases (i) and (ii), these will comprise also aspects of process phase (iii) analysis, integration and interpretation, as well partly (iv) risk and impact assessment. It should be noted that the scenarios for the proof of concept are also being discussed with other Mine Action Centres and Mine Action Operators (NGO's and Commercial) to get a broader feedback in the user needs assessment as well as the development of the business model required by the SADA terms of reference.

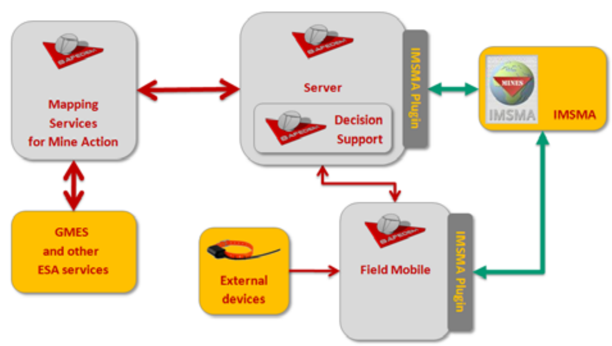

Figure 12. SAFEDEM high level SADA concept.

INSA Consortium

INSA Services proposed

Services proposed are classified in four categories or groups related to the phases of the mine action activities:

- ***General Assessment***: a complete service providing strategic information for planning and prioritization of mine action activities is defined for this stage of the land release process, including information about real contaminated areas (better SHA delimitation), socioeconomic impact information and cartography support, which will be an advantage for the planning tasks and Land Impact Survey (LIS) activities.

- ***Non Technical Survey***: two services are defined for this phase, with the main objective of providing confidence data about the evidence of mine/ERW presence and absence in a specific region or area. The first service focuses on the detection of visible craters, destroyed bridges, destroyed infrastructures/buildings, etc. (evidence of mine/ERW presence) and the second one focuses on the detection of land use changes on a yearly basis to indentify which lands can be released (evidence of mine/ERW absence).

- ***Technical Survey***: for the technical survey phase the SADA system will provide a service describing and classifying in detail the vegetation and the soil type presented in a specific region or area, which will improve the technical survey planning tasks achieving a more efficient deployment of the technical assets in the field.

- ***Post-clearance and report:*** once the demining activities are finished the user demands a monitoring tool in a long term basis to provide donors verification of the invested donations by providing information about the use of the released lands. There is also a need of a monitoring service showing the evolution of the demining activities. These two factors will be provided in the service defined for this phase.

Communication and navigation support services will also be provided for field site operations. It is assumed that any of the previous phases may involve field deployment, so there will be support for all the phases of the land release process. The main communication service to be provided is voice communication between the field offices and working sites located in remote areas where the existing telecommunications infrastructure does not provide coverage. Navigation support service will be provided with different degrees of accuracy for the different phases of the land release. It is understood that Technical Survey (TS) teams may need high accuracy positioning data unlike LIS or non-TS teams, and this fact must be considered.

INSA Concept description

The concept definition takes into account at least the Information Management System for Mine Action (IMSMA), a tool that is already well-established in the community. It is integrated into the architecture for the services provision. Space assets are a key part of the architecture, helping to fill the gaps identified with the already used technologies. The main blocks composing the SADA system are depicted in Figure 10.

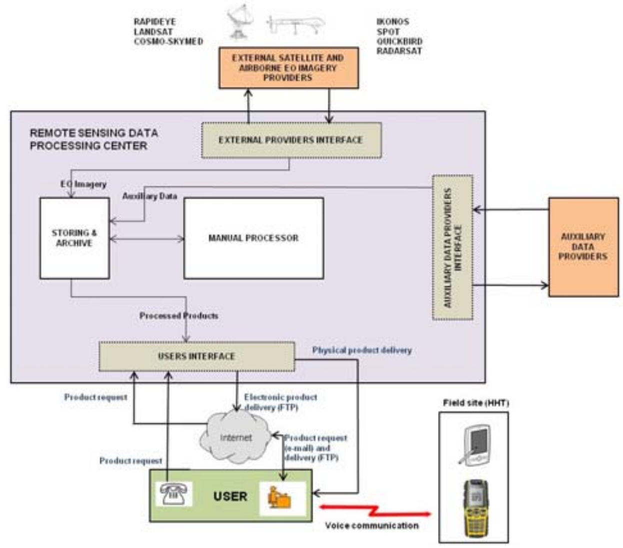

Figure 13: INSA SADA system main blocks

The Remote Sensing Data Processing Center (RSDPC) will be in charge of processing the remote sensing data and making the resulting products available to the users. Therefore, it will carry out the generation of the different products demanded by the users and the delivery to them. The RSDPC is also a front-end interface to the remote sensing and auxiliary data suppliers (through the mentioned interfaces) and will be in charge of products distribution to the users.

Within the RSDPC, The Processing block will prepare all remote sensing data acquired by the existing airborne, satellite sensors, and auxiliary products and generate the different products and related metadata. Finally a Database Manager is needed in order to facilitate the integration of the indicators of the different products, and to provide storing and archive capability (geospatial database of the products and user information classification).

The "User Community" has been included in a single box to state that the user of the system can be any organization related to the mine action community: a decision maker, mine action center, NGO, commercial company, military, etc.

Finally field demining sites are depicted in order to consider the fact that a subset of the services to be provided by the SADA system will apply exclusively to these field sites (namely the Handheld Terminals), specially navigation and communication services.

INSA Proof of concept

The INSA proof of concept shall be the opportunity to validate the system and service design. Users from Mine Action Coordination centre of Afghanistan

(MACCA) and Bosnia Herzegovina Mine action centre (BHMAC) shall be receiving the products generated by the consortium for their validation. This will be a good opportunity to test the critical technologies against user data and requirements and create user awareness about the integrated technologies capacity.

Some examples included in the PoC shall be the suspect area reduction using a non-technical method and provision of non-biased information of results and socioeconomic impact achieved after the mine action activities.

V. CONCLUSION

Land Release in Mine Action is a process involving a multitude of possible scenarios and technologies. There is a clear need for an end-to-end assistance service for enabling Mine Action land release. the service should support planning, categorization and prioritization of geographical areas and scenarios to be dealt with for realising maximum socio-economic benefit. Field data collection and reporting should be improved. All services should be in line with the already ubiquitous IMSMA software.

Stand-off detection could be used at various levels of the land release process to support risk mapping, impact mapping, minefield and ERW-contaminated area detection and eventually to help to couple the most appropriate detection technology to meet field conditions.

As far as detection of individual mines or ERW itself is concerned, the main driver is the need for near flawless detection probability, requiring sensitive detection methods that offer a reduced false alarm rate. To make a difference, Minefield, ERW and mine detection technologies should be fieldable, cost effective, reliable, and discriminatory. In many cases, multiple detection technologies may be employed and the true benefit may come from their optimal combination and fusion of data.

The land release process is expected to be improved by space enabled services currently being defined by the three SADA consortia. Proof of Concepts are currently being initiated, and, if successful, commercial services will be developed as part of one or more Demonstration Projects.

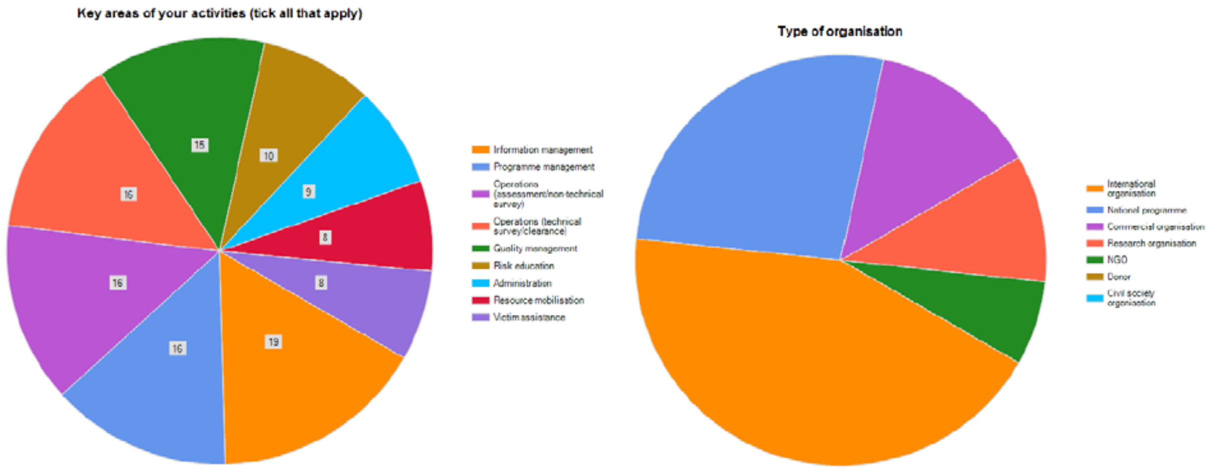

Figure 14. ESA survey respondents analysis.

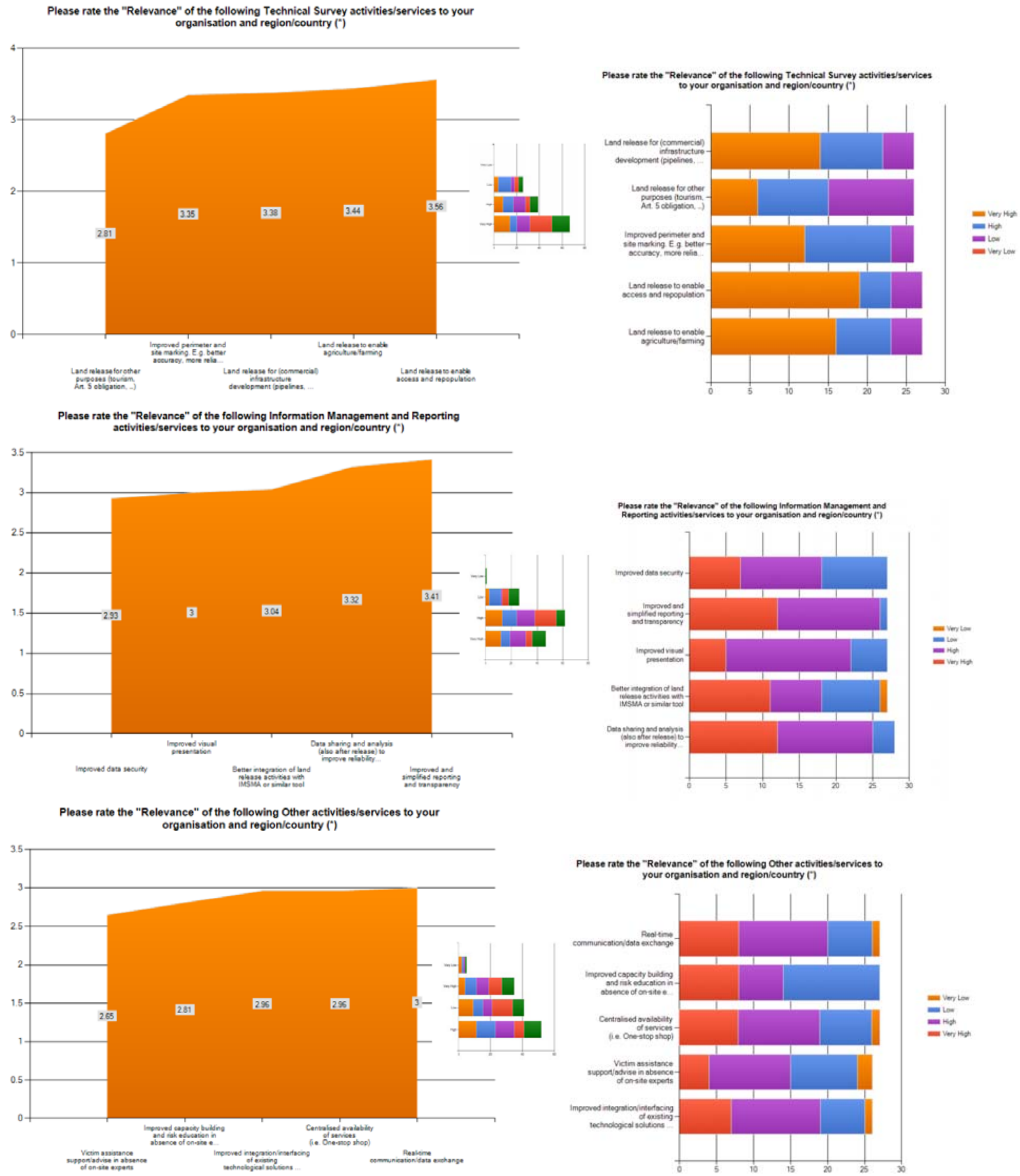

Figure 15. ESA survey results of Mine Action user interest in services with space asset elements (30 responses intermediate result).

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