→ BLOCKCHAIN AND EARTH OBSERVATION

White paper

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European Space Agency

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1. EXECUTIVE SUMMARY

As a potential future roadmap for Distributed Ledger Technology (DLT) is defined in the selected Earth Observation (EO) priority domains, there is a need to differentiate between conceptual applications of DLT, their business potential, and how feasible they are to implement.

The steps proposed in this White Paper, therefore, aim to sort out hype from reality, while taking into account different levels of DLT maturity, the specificity of EO technologies, and the prospects offered by distributed processing for the next generation of digital EO satellite services and operations.

The key findings can be summarised as follows:

1. Distributed ledgers (or blockchain) are not yet considered to be immediately applicable to space systems operations and EO data exploitation. However, this perspective may change rapidly, as the technology improves and new examples of the added value of DLT are progressively revealed.
2. It is important to demonstrate how blockchain technology can help to solve existing problems and issues for the EO sector, or open new opportunities for data or services delivery, with lower costs, higher performance, and/or a better fit to user needs.
3. ESA can ensure an **appropriate framing of the challenges and opportunities** for the EO community, including potential applications which might appear as blockchain technology matures.
4. Understanding the limitations of blockchain is important, in order to frame the boundaries for such future applications.
5. The long-term objective for ESA is to **deliver an entryway** for the European EO industry, R&D and science community while the adoption of DLT intensifies in other sectors of the digital economy.
6. ESA, as a global leader in EO, is best placed to proactively scout the opportunities offered by this emerging technology. Addressing projects at low TRL levels, testing the feasibility of DLT solutions, and facilitating user uptake will all be key to discovering disruptive innovations in this domain, and to their field testing.
7. There is as yet no existing cohort of users of DLT in the EO sector, and no legacy players. There is thus an opportunity to be at the cutting edge of this technology, and to define best practice for the community. Development of the applied research agenda and use cases must, however, align with the operational needs of users and industries in both technology domains.
8. By mapping existing blockchain activities, and analysing how DLT is used across other industries, the EO community can gain an important understanding of blockchain potential and its constraints. This can be achieved by transferring knowledge and expertise between DLT/blockchain developers and EO science, research and business communities. Dedicated steps are therefore proposed to bring entrepreneurs and ideas together, in order to encourage cross-fertilisation and collaborative developments.
9. Efforts to capture the attention of key EO stakeholders, from industry to decision-makers, should be increased, by informing them about the rationale and growth potentially achievable through the DLT/EO crossover. This stakeholder engagement should be carried out on a regular basis by organising joint workshops, events and sessions alongside regular EO events, as well as a suite of pilot projects to be implemented in 2018-2022 timeframe.

2. PURPOSE AND SCOPE

This White Paper captures the outcome of a community-led Blockchain Workshop held at ESA/ESRIN during Φ-Week (phi-Week), 15 November 2018 (see the participants' list and presentation topics in Annex 1).

The workshop developed important insights into the opportunities and challenges of DLT applications, and highlighted the role of the public sector, NGOs, academia, and industry in leading innovation in this domain. Synthesising these initial ideas and contributions allowed the participating experts to:

- Informally assess the state of play when it comes to adopting DLT in the EO sector,
- Explore the potential value of a high-level Research and Innovation (R&I) effort on this topic, both at the ESA and European level
- Define the steps necessary to develop pilot projects and partnerships across existing networks and initiatives on the DLT/EO crossover
- Articulate recommendations and an Implementation Roadmap.

This White Paper is intended as a dynamic report capturing the current readiness, needs, and expectations of the EO community, relative to facilitating potential DLT technology uptake. It will be updated on an annual basis so that progress can be measured against the Roadmap milestones, and to share feedback from forthcoming pilot projects.

Terminology

'Blockchain' is a particular type of data structure used in some distributed ledgers, which stores and transmits data in packages called 'blocks', connected to each other in a digital 'chain'. Blockchains employ cryptographic and algorithmic methods to record and synchronise data across a network in an immutable manner.

A **Blockchain transaction** can be defined as a small unit of task, stored in public records. These records are also known as 'blocks'. These blocks are executed, implemented and stored in blockchain only after validation by the entities in the blockchain network.

Cryptocurrencies are a subset of digital currencies that rely on cryptographic techniques to achieve consensus, for example Bitcoin and Ethereum.

DApp is a decentralised application, running on a decentralised peer-to-peer network as opposed to running on centralised servers.

Digital currencies are digital representations of value, denominated in their own unit of account. They are distinct from e-money, which is a digital payment mechanism, representing and denominated in fiat money.

Distributed Ledger Technology (DLT) refers to a novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers). This technology allows for transactions and data to be recorded, shared, and synchronised across a distributed network of different network participants.

Ethereum is the open-source, public, blockchain-based distributed computing platform and operating system, featuring smart contract functionality.

The **IoT** – Internet of Things – is a network of objects, linked by a tag or microchip, that send data to a system that receives it.

Nodes are network participants in a distributed ledger network.

Public Key Cryptography is an asymmetric encryption scheme that uses two sets of keys: a public key that is widely disseminated, and a private key known only to the owner. Public key cryptography can be used to create digital signatures, and is used in a wide array of applications, such as HTTPS internet protocol, for authentication in critical applications, and also in chip-based payment cards.

Smart contract is a computer protocol intended to digitally facilitate, verify, or enforce the negotiation or performance of a contract. In this paper 'smart contract' is mostly used in the sense of general purpose computation that takes place on a blockchain or distributed ledger. In this interpretation, a 'smart contract' is not necessarily related to the classical concept of a contract, but can be any kind of computer program or code-executed task on blockchain.

Token is a representation of a digital asset. It typically does not have intrinsic value but is linked to an underlying asset, which could be anything of value.

Verifiable Claim is machine-readable information that can be verified by a third party on the Web. Such a claim is effectively tamper-proof and its authorship can be cryptographically verified. Multiple claims may be bundled together into a set of claims.

3. INTRODUCTION

Distributed Ledger Technologies (DLT) – also known as blockchain – allow for transactions and data to be recorded, shared, and synchronised across a distributed network of different entities participating in the network.

Blockchain technology is often referred to as having a revolutionary potential for transforming the 'digital economy' by replacing monolithic and centralised management structures (such as banks, stock exchanges and government agency functions) by a network of distributed and inclusive systems, in which people and organisations can participate in open, transparent and direct collaboration (peer-to-peer) ecosystems. This vision of information and value exchange, conducted in a trustworthy way and without central control authority, is driving substantial investments into various startups and blockchain enterprises.

While businesses built around this technology have achieved varying degrees of success, it is evident that the main impact by far of DLT until now has been in the financial sector and capital markets ecosystems. Over the past few years, several global financial institutions have experimented with a number of blockchain-operated digital products and transactions. Their objective was to explore options for data transfer, fraud reduction, cross-border payment, and cryptocurrency functions.

At the same time, the industry leaders and policymakers across different sectors of the economy, and in public policy, have launched many initiatives (including dedicated innovation hubs) to investigate the potential of blockchain for non-financial applications. Areas of interest currently include: land administration, supply chain management, energy, health, education, and carbon market trading, to name but a few. There is thus a growing consensus that recognises the potential for large-scale blockchain use for a wide range of industries and services.

The European Space Agency's (ESA) role is to catalyse European innovation within the Earth Observation sector by enabling bold EO innovative solutions. ESA accelerates their adoption within the European research and business communities. It brings together expertise to test relevance and prototype high-impact new technology. It invests in highly innovative and disruptive concepts with a high risk of failure. Finally, it disseminates the lessons learnt and knowledge throughout Europe's EO community.

While the adoption of blockchain intensifies in other sectors of the digital economy, the aim of this White Paper is to define the key focus areas for the EO sector. The following list outlines specific issues and challenges identified at a community-led Blockchain Workshop, held at ESA/ESRIN during Φ-Week, 15 November 2018:

- What are the main forces driving blockchain innovation?
- What is the expected impact of distributed processing solutions combined with other emerging technologies, such as IoT, AI and Big Data?
- What are the main blockchain initiatives being undertaken (on a European and global level) including flagship projects and priorities on the EU level?
- How does blockchain enter the EO and space technology domain (short term/ long term)?
- How can blockchain be used to address emerging challenges in EO?
- How can blockchain be incorporated into EO product and service design?
- How can EO be incorporated into blockchain applications?
- Can new tools and methods be built where blockchain and EO cross over?
- What due diligence should be undertaken across these new technologies and value chains, including during the pilot project phase?
- What are the respective roles of the EO and the blockchain industry, academia, and the R&D community?
- What are the objectives for the EO community?
- What are the next steps?

4. CHALLENGES AND OPPORTUNITIES

4.1 Understanding the landscape

In the most basic sense, Distributed Ledger Technology is seen as a tool to advance the global digital economy. However experts also agree that blockchain technology is underpinning a new digital industry sector in its own right. [1]

The term 'digital economy' embraces digital (computerised) technological infrastructure such as digital data and data handling infrastructure; ICT goods and services; data centres; online platforms; and platform-enabled capabilities, as a foundation of economic and societal growth.[2] The key technologies that are expected to have the greatest impact on this ecosystem over the next decade are: IoT, autonomous vehicles and drones, robotics, 3D printing, Artificial Intelligence (AI), augmented and virtual reality, digital traceability and blockchain. They are projected to enable socio-economic transformations which may unlock $100 trillion market for business, science and society.[3]

In this context, blockchain technology is still treated with caution. This is because only a handful of use cases across different market segments have proven the potential of blockchain in large-scale operational use. Nevertheless, the concept of digital supply chain traceability (i.e. based on blockchain) is expected to define the role of new communication architectures (i.e. P2P) and cryptographic data structures in the next generation of information services. It will have a direct impact on the future of the management, processing and sharing of digital data, and the digital representation of physical assets and transactions.

4.1.1 The state of DLT

Distributed ledgers have several important characteristics. They are a broader category of 'shared databases', defined as a shared record of data across different parties. They are generally categorised as permissioned or permissionless, depending on whether network participants (so-called 'nodes') need permission from any entity to make changes to the ledger (the database), or whether the ledgers can be accessed by anyone or only by the participating nodes in the network.[4] According to one definition, blockchain is a particular type of data structure used in some distributed ledgers which stores and transmits data in packages called 'blocks' that are connected to each other in a digital 'chain'.[5] The terms 'blockchain' and 'distributed ledger' systems (DLT) are used here interchangeably.

'The main thing distinguishing a blockchain from a normal database is that there are specific rules about how to put data into the database. That is, it cannot conflict with some other data that's already in the database (consistent), it's append-only (immutable), and the data itself is locked to an owner (ownable), it's replicable and available. Finally, everyone agrees on what the state of the things in the database are (canonical) without a central party (decentralised)'.[6]

Experts agree overall that the primary reason for using blockchain is to decentralise, that is, to secure storage and transfer of information by removing the single point of failure, and to promote integrity (immutability) and ownership of data.[7] Blockchain is also built upon the concept of distributed ownership of the node infrastructure, which is suitable for sharing and handling data more directly and in a more transparent way. Therefore users tend to adopt it in order to have more control over the provenance and use of data, to monitor data quality, to guarantee data security, or to build trust in data.

The various characteristics of DLTs (i.e. public vs private; permissionless vs permissioned) define different types of blockchain platforms currently available on the market. They can use different programming languages, node ecosystems, consensus mechanisms (there are various types), pricing or governance structures. Some of them, for example, have a high utility in multiparty financial transactions; others are optimised to support business segments and processes.

Bitcoin and Ethereum are currently the most popular public platforms widely applied in fintech (although Ethereum can be deployed as a private network). This is followed by a large number of private (or permissioned) platforms, such as Hyperledger or R3Corda. IBM is working on a concept of 'public but permissioned' blockchain, which would converge both concepts. There are also specialised solutions such as platforms like IOTA which offers an open source programme particularly suitable for machine-to-machine (M2M) and IoT communication. Another is KSI Blockchain, which is designed for very specific applications requiring proof on integrity and time of data.

This diversity of operational concepts currently supports various groups of users and stakeholders, who may have different needs around the so-called Minimal Viable Ecosystem for projects and product development (i.e. different requirements for sharing information, business models, and governance of user groups). The proliferation of platforms and businesses is however also resulting in the fragmentation of products, and their possible lack of interoperability. In view of this challenge, the key global cloud providers have started to offer Blockchain-as-a-service (BaaS), to enable more rapid standardisation and mainstreaming of the selected solutions. Microsoft has partnered with ConsenSys to offer Ethereum Blockchain as a Service (EBaaS) on Microsoft Azure. Amazon Web Services (AWS) has introduced the open source frameworks Hyperledger Fabric and Ethereum in its Amazon Quantum Ledger Database (QLDB) and Amazon Managed Blockchain products.

Blockchain platforms can be categorised not only by popularity amongst clusters of experts and developers, but also by levels of maturity and relevance to markets. In the financial domain, where blockchain platforms have proven viable (i.e. in cryptocurrency, peer-to-peer money transfer and insurance), there are solutions being adopted by many banks and financial institutions.

The non-financial sector is currently focussed on applications for the authentication of digital data, digital identity, logistics chains, real estate transactions, and Smart Contracts (for value exchange). For example, the Government of Estonia has been testing the technology, with a view to implementing it in e-governance applications, since 2008. Since 2012, KSI blockchain has been in operational production to protect national data, e-services and smart devices both in the public and private sector.[8] The automotive industry is also actively adopting blockchains for autonomous driving, exchanging data and payments, tracking mileage, and registering assets.[9] The Swedish Landmateriet (cadastral agency) has successfully implemented solutions to enable the creation of a permanent register of real estate assets and the execution of transactions on blockchain. The intention is to improve the transparency and speed of operations by removing the need for expensive, time-consuming clearance of real estate settlements. As a result, such contracts can be effected in days rather than months, with a significant reduction in transaction fees. Sweden, Georgia, Ukraine and Rwanda are currently launching initiatives to use this technology as the basis for their land registers. Companies including ING, Deutsche Bahn, Telekom, Air France-KLM, Porsche, Daimler, Allianz, Siemens and many others have also officially expressed an interest in launching a blockchain-based project in the foreseeable future, and this list is growing.

4.1.2 Rationale and objectives for EO

Distributed ledgers are not yet considered to be immediately applicable to space systems operations and EO data exploitation. However this perspective may change rapidly as the technology matures and new examples of the added value of DLTs are progressively revealed.

At the moment, there is a need to demonstrate how blockchain could help solve existing challenges for the EO sector, and open up new opportunities for data or service delivery with lower costs, higher performance, and a better fit to user need.

For the EO community the game-changing technologies have thus far been: AI, cloud infrastructure and Big Data applications and analytics. These advances in information technology (IT) have facilitated the paradigm shift in EO known as Space 4.0. **Cloud-based computing**, for example, enables more efficient storage and exploitation of EO data. Taken together with non-EO datastreams (i.e. in situ, socioeconomic data, other sensor data) it allows us to handle much larger volumes of records, covering longer timescales or providing more continuous coverage and monitoring. New algorithms and the robust training of large-scale deep neural networks have opened up the potential for new service areas in a vast variety of customer/user market segments, across a range of industries — from agriculture to transport to energy, financial intelligence and site monitoring. **AI and Machine Learning** are now applied to develop predictive analytics, using both EO data archives and new dynamic acquisitions. With the available processing techniques and volumes of EO data, including in near-real time, a considerable number of business intelligence solutions have been successfully developed and/or commercialised for public and private sector users.

These emerging capabilities are set to become a main market driver for the EO service industry in the future.[10] Existing EO data and information service supply chains are, however, still mostly linear: the value chain springs from raw EO data supply, data processing and information product development and sales. The adoption of distributed data access solutions, **integration with M2M direct communication, and IoT ecosystems**, has the potential to change these linear supply chains into a set of dynamic data networks in which EO would become a key element in a larger universe of 24/7 connectivity. [11]

This is also where questions related to the **distributed data access** and **new digital data standards** come into play. The ongoing W3C standardisation efforts aim to facilitate the conditions to manage, access, and share these datastreams effectively. They could help unlock opportunities from EO integration with IoT and M2M, such as the development of solutions for interoperable data identity structures, the ability to query data, to verify provenance and immutability (proof that data have not been tampered with).

In the future, such new data standards may also enable better handling of decentralised digital identities (DIDs), and may ultimately be a key enabler for the **Verifiable Claims Data Model** based on blockchain.[12] Such machine-readable information, which can be automatically verified by a third party on the Web, is intended to lay the foundation for a new economic model, based on **massive, multisource and real-time data, which will underpin the next generation of information services**.

In order to **stay relevant and active** in these Big Data supply chains, the challenge will be to upgrade the EO sector in the eyes of the marketplace, which has a strong focus on **IoT, sensor interconnection, information verification, M2M fusion and Smart Contracts**. As things progress, digital transactions will take place in an increasingly automated way, without intermediaries or brokers, and involving both human and machine interaction and data sharing in the value chain. New digital data structures and integration process solutions that allow us to lower the administrative cost of such operations (i.e. contract signing, invoicing and settlements), or share revenues for collaborative inputs, will therefore be breaking new ground for the EO industry.

Moreover, for many forthcoming Smart Contract-enabled business applications, there will be a critical need for trusted datastreams and certified information (highly processed data) to enter the code-executed transaction record, in order to further the operation and/or Smart Contract execution. EO sensor networks and associated EO services and algorithms could become functional 'nodes' in a Smart Contract value chain, by connecting the physical environment to digital ledgers: EO can back up a record of information about product ownership or provenance with the physical representation of assets, estimated from remotely-sensed physical objects across the whole electromagnetic spectrum (also known as Digital Twins).

In the short and long term, however, there are challenges around how to handle large volumes of EO data. These are already reaching the Petabyte scale. For example, to date, about 12 million digital products are available for download, equivalent to a total volume of 111 Petabytes through the Copernicus Open Access Hub, with an outlook of minimum 15+ years of continuous, global observations. For EO data providers, such as ESA, the need for advanced EO data management solutions will only grow. Maintaining, managing and processing such large volumes requires processing in the cloud as well as processing chains deployable in multiple facilities and cloud infrastructures. There is thus an interest in data structures that can **provide a secure, definitive reference for data distribution and tracking, as well as the record**

of processing steps. The quality of long term EO products and services needs to be ensured, especially given that much EO product generation and processing will be taking place on the fly.

Improving and redefining the way EO data and services are distributed and processed, with a guarantee that processing chains will be delivering the same (high) quality of data products, is going to be a key driver for innovation in ground segment capabilities. Take the Sentinel Product Life Cycle, for example, which requires the labelling of EO data to make it more searchable and interoperable. Protecting data from tampering, and software and production chains from infringement or errors, is going to be increasingly important vis-a-vis cloud-based processing chains. **The capacity to certify the integrity of a product by providing traceability and proof of EO value chain immutability and its authenticity has a high utility value**.

To explore such certification functions in EO, data processing steps need to be attributable, and may require the development of schemes to manage the digital identities (signatures) of contracted/trusted partners, allowing them to, among other things, 'certify' the validity of individual products; 'certify' the validity of lists of products; invalidate individual products and entire product baselines; record and document reasons of invalidity; identify product replacements, and so on.

Such certification and process management functions are applicable to a range of EO functional market segments in downstream, upstream and midstream. For example:

- **Mission planning and operations** i.e. devising and monitoring the implementation of observation plans, including the management of tasking requests, logging and tracking of command and control events
- **Digital supply chains** in both ground segment infrastructures and satellite on-board processing to track and resolve conflicts in data processing steps and to identify gaps
- **Physical supply chain in EO manufacturing** to improve overall transparency and effectiveness of the flow of goods and financial services.

Such quality assurance is also particularly applicable to databases and systems vulnerable to external cyber-attacks, as well as any specific applications requiring strengthened trust in data veracity or for better (autonomous) risk management.

It is also going to become increasingly important to improve the tracking of data processing steps, and the attribution of software elements or data use in a value chain. On the one hand, verifiable audit trails could be used to **ensure the authenticity and quality of data and processing techniques (both software and methodologies)**. This would result in building trust in EO data chain attributes for decision-making purposes (i.e. for security applications, law enforcement, insurance, commodity trading, etc.). On the other hand, better data or product administration, as well as the attribution of originality, especially in the open source domain, would improve the overall protection of Intellectual Property Rights in the platform-based economy.

From the perspective of the data analytics industry, there are still many obstacles that hold back the accessibility and use of EO information products and services, and the global uptake of such services and imagery. Despite an unprecedented improvement in data access policies (c.f. the 'full, free and open' licensing scheme for Sentinel data), challenges of limited bandwidth and processing capabilities exist, especially in those parts of the world with a digital divide (limited access to the internet), or where data infrastructures are not structured or digitised.

As a result of such obstacles EO datastreams currently tend to benefit well-established clusters of high-end expertise which are able to integrate EO technological solutions into their workflows in Earth science and research, and to some extent to the private and the public user sectors. A vision of democratic EO data access and use is still far off. Bringing down the barriers for use of EO data is thus a top objective.

Exploring new opportunities to empower underrepresented users of EO is paramount. **This could be achieved by stimulating novel collaborative arrangements, in which knowledge and data sharing, and exchange of value for contributions, is an integral part of the marketplace**. Such collaborations might involve, on the one hand, professional data brokers, or on the other hand farmers, citizens, or local groups who can take full custody of their data. There is in reality an urgent need for solutions that can help to collect and integrate non-EO data into services, make data reliable and interoperable, register data and contributions, and propose attractive revenue sharing schemes to incentivize collaborations.

Collaborative arrangements could explore the option of monetising or tokenising community inputs (i.e. by providing socioeconomic data, in situ data, etc. as well as proof of contribution). They could equally explore monetizing processing capabilities (i.e. hosting data and processing power on the distributed computers). This might have the effect of breaking monopolies, or opening existing clusters of expertise to new users and beneficiaries. Such value exchange might also solve one of the critical problems in EO: the availability of reliable, validated and systematic ground truth information as well as datasets for training of AI models and Machine Learning.

Accessibility is just as important when it comes to handling proprietary or commercial data, where, in addition to the cost implications, there are also licensing restrictions around data access and use. The concept of machine-readable information, which can be independently verified by any of the supply chain actors, provides the opportunity to develop **new EO digital data licenses which could be programmable and self-executing based on user profile, identity or task** undertaken in the online/platform environment. This could open entirely new ways of accessing data such as EO data rental, and new trading schemes such as tokenization and smart contracts.

Finally, **data security and protection** should be taken into account as a vital element in the future of EO services. Large repositories and databases of various economic, financial and personal data (including location data) are being made increasingly available, whether open or sold commercially to data analytics or data brokering companies. The success of future EO applications will depend on access to this wealth of digital data. At the same time, protection of sensitive non-EO databases from theft or interference, must be ensured, and in accordance with regulations such as EU GDPR (the EU General Data Protection Regulation). **There is therefore a need to demonstrate that the benefits of sharing sensitive data outweigh the risks, and that there are technological solutions for data protection that lower those risks while providing high analytical utility**. This need also reveals the demand for privacy-focussed and data security-driven applications, which could enable large groups of data to be simultaneously proprietary (or private), secured and shareable.

To summarise, the **preliminary list of priorities** relevant to blockchain solutions for the EO community are as follows:

- Supply chain tracking in upstream, midstream and downstream segments
- Proof of the immutability of EO data; traceability of EO data and information products; automated certification and auditability
- Digital Identity solutions
- EO data access, and data trading
- Intellectual Property Rights

- Incentives in community collaborations
- Digital representation of assets for emerging DApps (Distributed Applications) services and Smart Contract execution.

4.2 Framing the challenge

In order to develop the framework needed to drive high-impact projects through industry, and research collaboration at the intersection of blockchain and EO, the following should be considered:

- An enabling environment
- The limitations of blockchain technology
- The basic needs of the EO community
- High level R&D topics
- Operational needs and potential use cases
- Legal, regulatory and ethical issues.

There is a unique and timely opportunity for ESA to lead the systematic analysis of these topics and explore blockchain technology concepts with the following objectives:

- To ensure an **appropriate framing of the challenges and opportunities** for the EO community, including:
    - Potential applications for enhanced EO data processing capabilities
    - Protection of EO databases
    - Authentication of algorithms
    - Certification of the value chain
    - EO data use analysis
    - Token engineering
    - Data standards
    - AI in distributed processing

- **To deliver an entryway** for the European EO industry, R&D and science community while the adoption of blockchain increases across other sectors of the digital economy.

In order to meet these objectives, it is of critical importance to:

- Enable the transfer of knowledge, techniques and expertise between DLT/ blockchain developers and the world of EO science, research and business applications (in both directions)
- Define priority areas to address real industry challenges
- Foster partnerships between DLT and EO industry players in order to stimulate development of innovative EO business solutions
- Empower the new generation of researchers, data entrepreneurs, and digital startups on the crossover of DLT and EO capability
- Harness the involvement across communities, users and contributors through novel collaboration schemes.

4.2.1 Enabling environment

The ecosystem of blockchain platforms and developers is growing fast and receiving increasing support from international and European investors and policymakers.

The **Blockchain startup ecosystem is very dynamic**. The industry raised nearly $3.9 billion through VC investments in the first three quarters of 2018 (280% growth when compared to the whole of 2017)[13].

However, the level of maturity of these enterprises varies greatly. The biggest sectors investing in technology exploration are by far finance and insurance, as well as ICT, which represented approximately 97% of the overall funds in 2017. They were followed by the energy, healthcare, education, transportation and storage, agriculture and real estate sectors.[14]

These proportions are, however, likely to change, in two ways. On the one hand, 2018 has revealed the bubbles in the cryptocurrency markets. The VCs are currently moving away from supporting speculative fintech solutions while a large number of developers focus now on demonstrating applications based on identified use cases and proving their viability.

Europe is closing in on North America when it comes to blockchain innovation. The UK, Switzerland, Germany, Estonia, Spain, France, Italy, Austria and Ireland have a lead in Europe, with blockchain companies developing many pioneering concepts in the fintech, identity management, healthcare, land transaction, transportation, automotive and energy sectors. Some examples include the Green Energy Blockchain Project in Estonia; the blockchain-based real estate register implemented by the Swedish Mapping, Cadastral and Land Registration Authority; a blockchain-based register of ships initiated by the Danish Maritime Authority as part of a ship and sea trade digitisation project; and peer-to-peer energy trading projects in Germany.

Added to this, European academic programmes and tech hubs are also stimulating DLT research and application development, with courses or degrees offered by Oxford, Cambridge, UCL, University of Northampton, the IT University of Copenhagen, the University of Nicosia, the Blockchain Centre in Vilnius, and the European Blockchain Centre at the Technical University of Copenhagen (ITU).

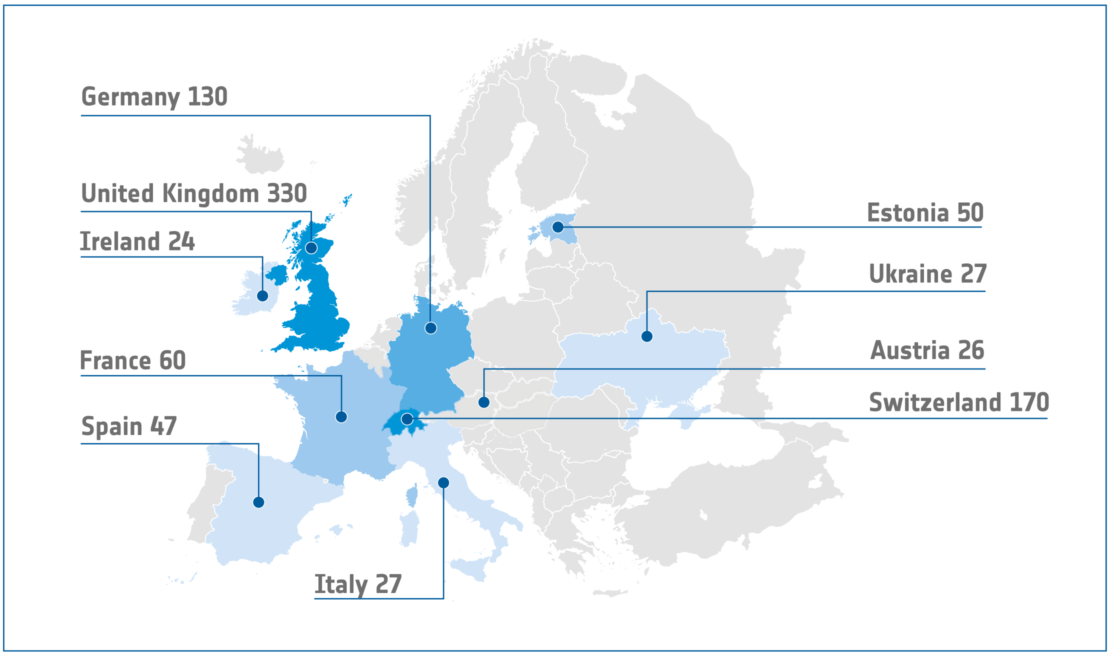

Figure 1 Europe's top 10 countries with the highest number of DLT-based companies Source: Crunchbase Data, Chain.de, Cointelegraph available at "Who's who in blockchain: An in-depth report on the DLT-based companies of Berlin" by Occurency.

Blockchain-related research is now fully integrated into the EU Digital Single Market Agenda. The European Commission (EC) has dedicated €80m to EU projects addressing blockchain applications, and has announced plans to increase funding by up to €300m by 2020 (under Horizon 2020). As a result, the European Union Blockchain Observatory and Forum was set up by the European Parliament in 2018 to analyse and report on a wide range of blockchain themes driven by the priorities of the EC. [15] One initiative, called 'Blockchain4EU: Blockchain for Industrial Transformations' is being implemented as part of the EU Science Hub to explore existing, emerging and potential applications based on blockchain and other DLTs in both industrial and non-financial sectors.[16]

In 2019, moreover, the EC, in cooperation with the European Blockchain Partnership (EBP) which was created by the EU member states and other stakeholders, has set out plans to develop the **European Blockchain Services Infrastructure (EBSI)**. This is intended to provide sustainable and EU-law compliant tools for potential development and deployment of the first set of cross-border digital public services based on blockchain.[17] These strategic initiatives are meant to give a dedicated boost to blockchain implementation and innovation in Europe.

This first wave of proofs of concept and pilot projects has demonstrated the growing interest in practical applications and use cases. At ESA, blockchain technology exploration was included as far back as the 2017 European Space Technology Master Plan (ESTMP), under the 'Big Data from Space' theme, within the General Support Technology Programme (GSTP). Several blockchain projects have also started in the EO domain with the objective of de-risking future activities, and paving a way for potentially larger-scale projects. The 'Blockchain for Space Activities' (BC4SA) project was developed within the GSTP to demonstrate how blockchain technology can be used to verify the integrity and provenance of ESA Earth Observation datasets independently, as the data is generated, moved across organisational boundaries, and ingested into analytics platforms.[18]

Another project focusses on Smart Contract implementation based on blockchain, aimed at unlocking new methods of EO data access via the cloud environment ('ShowmySite goes Blockchain').[19] Furthermore, CTEO, a 'Blockchain for EO' project, is delivering a prototype software development kit (SDK) to test EO processing on existing DLT platforms.

The Open Geospatial Consortium (OGC) has also recently initiated a review of DLTs and blockchain initiatives, to analyse their potential impact on current and future OGC standards. Topics include: the requirements for geospatial standardisation of DLT (including blockchain); progress of the Crypto-Spatial Coordinates (CSC); and progress of the FOAM open protocol, which is proposed as the interoperable standard for location data on Ethereum. In similar fashion, the International Telecommunication Union has established three focus groups to work on blockchain-related standardisation: data processing and management, DLT and digital currency (ITU-T: Focus Group on Application of Distributed Ledger Technology). [20]

Finally, the **International Organisation for Standardisation (ISO)** has established a technical committee, ISO/TC 307, to develop new standards on blockchain, and currently has 11 standards under development.[21] The EC participates actively in this forum, driven by its interest in topics like Smart Contracts, which might be an area for future EC regulation, especially if blockchain-based Smart Contracts are to transform into legally binding and enforceable legal instruments, in addition to their function as an instruction-giving code.

4.2.2 Limitations

By mapping existing blockchain activities, and analysing how it is used across industries, the EO community can gain an understanding of the potential of this new technology beyond purely conceptual considerations – and its limitations. [22]

At the moment, many of the benefits of blockchain are theoretical. What is more, there are many examples in other industries of DLT-based applications being developed without a true or deep understanding of the problem they were supposed to be solving, and where the added value might lay. EO can learn from these early unsuccessful pathways and focus its efforts first on clearly identifying the problems to solve, and then devising appropriate solutions. It is therefore important to navigate the expectations associated with DLTs carefully, and to evaluate the maturity and state of adoption of distributed ledgers, including their limitations, as they move through the 'hype cycle' (see Figure 2).

HYPE CYCLE FOR BLOCKCHAIN BUSINESS, 2018

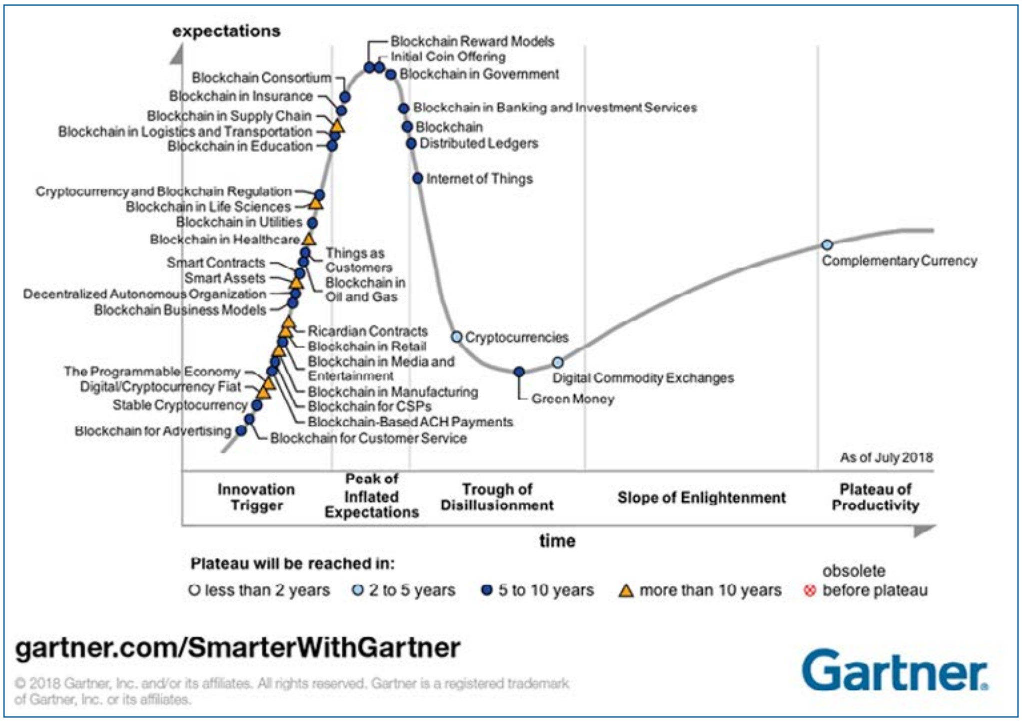

Figure 2 The Reality of Blockchain. Credit: Gartner; Contributor: Heather Pemberton Levy, October 16, 2018 at https://www.gartner.com/smarterwithgartner/the-reality-of-blockchain

Overall, it has been well established that various blockchains can be difficult to work with and scale, expensive to maintain, controversial from the environmental sustainability perspective, and hard to upgrade.[23] The four most widely quoted limitations of blockchain are cost of creating and using such systems, scalability, governance and security of private key management.

Scalability is often referred to as 'blockchain's biggest problem'.[24] **There are significant monetary and infrastructure costs related maintaining and updating a blockchain-based database at scale**. In the distributed public databases, each 'node' stores all transaction details, in order to verify a transaction's validity for each of the events in the network. This means that data has to live in hundreds or thousands of places rather than in a single place, which results in the need of increasing computing resources needed to run such operation or risk performance degradation. This is a serious constraint, especially given that interconnected IoT or sensor networks may involve billions of interconnected devices (nodes), implying that the requirement for transaction volume may be several thousand times the current DLT capacity.[25] In this sense, existing centralised databases might be cheaper to maintain and already offer sufficient levels of consistency and reliability within the realm of their standard evolution cycles (updates).

A second limitation may be that the very hype associated with blockchain may affect the legacy information systems negatively. For example, experts agree that, when it comes to physical supply chains, 'the real innovations are the sensors that connect the digital with the physical world, not so much the storage mechanism used to record them'.[26] There is a need, then, to underscore this point as hybrid data networks are being developed, involving both blockchain and sensor technology, and as decisions are made concerning the suitability of the existing ICT systems. The danger is that blockchain hype, especially if inflated, may lead to eliminating or retrofitting existing IT solutions, impacting jobs and skills, or diverting investments from other sectors of the knowledge-based economy, without providing a real added value.

This risk can be mitigated by drawing attention to the real industry problems revealed by blockchain: a need for timely, accurate, transparent and reliable data records. This revived attention can be used to support an ongoing effort to collect and digitise data about the Earth's environment, its populations and its economy in order to ready the data solutions for all kinds of information services (including both EO information services as well as verifiable data chains based on blockchain).

Thirdly, governance of DLT platforms is an important consideration. In principle, in public blockchains, any kind of public, private, or individual entities can contribute to a chain, and no single entity owns the chain. The costs of putting data into the system can therefore be very low, and clusters of users can add 'useless' data into a chain, if there can benefit from it.

However, if the ***wrong*** data is inserted into the chain, the added value of such a database – its traceability and transparency – is effectively voided. This is known as the 'garbage in, garbage out conundrum', considered to be one of the weakest points of public blockchain platforms.[27] In reality blockchain should be used to understand who put the data in, not if data is true. Thus it is possible to effectively solve the question of identity access control via blockchain solution.

This is an important issue as various commodities move through physical supply chains (i.e. the forestry supply chain, the agriculture supply chain, the transportation supply chain, etc.). There could be many cases where traders or brokers may want to obscure information going into the transaction record. Therefore, experts agree that **input data quality control has to be wired into the platforms (Decentralised Applications or DApps)**. To achieve that, it is necessary to provide the right incentive structures for contributors. This may require curating the reputations of participants in the chain, to make sure partners can be trusted. The governance, especially of non-public networks (permissioned blockchains) may have to include the continual vetting of entities running the 'nodes' to ensure they are trustworthy and reliable. However, curation of contributors may involve an additional overhead – access control layer – and, as such, reveal more reasons to rely on legacy distributed database technology, rather than blockchains.

Finally, **protecting cryptographic keys** (the secret code that unlocks the cryptographic protection of the asset), and digital wallets, remains a top concern for the community.

This is not a definitive list of blockchain limitations, as the technology is developing fast and is constantly improving. Nevertheless, it is necessary to frame the boundaries for future applications, define the context, keep up to date with new developments, and interpret findings of pilot projects as they appear at different stages of the technology's maturation.

4.2.3 Basic needs

There is a fundamental need to capture the attention of key EO stakeholders, from industry to decision-makers, concerning these developments and to inform them about the rationale and growth potentially achievable through DLT and EO crossover, as well as the limitations of blockchains.

Blockchain is now recognised as an emerging domain of the European Space Technology Master Plan (ESTMP), with applications for **data quality assurance (veracity), data privacy, security and tracking**. Upcoming developments under the ESA Technology Development Element will expand ESTMP to studies on the topic of **Synergic use of Blockchain and Deep Learning for space data and In-Orbit Demonstration of Satellite Integration to Distributed Ledger Systems**. These will showcase the unique added-value features that satellites can bring to distributed ledger applications. Under ESA **Φ**-Lab, three pilot projects have already been initiated to study the feasibility of: delivering solutions for EO data quality tracking; algorithm protection and processing; and cataloguing and distributing data via distributed systems. In addition, the ESA Business Incubation Centre recently opened a small-scale kickstart facility for start-ups wanting to explore blockchain for the space sector. [28]

Dedicated steps are now also needed to build a community of professionals and bring entrepreneurs and ideas together consistently, in order to encourage cross-fertilisation, joint developments and the exchange of lessons learnt. This can be carried out by organising joint workshops, events and sessions alongside regular EO events.

In this context, the ESA **Φ**-Week Blockchain Workshop was the first of its kind in Europe, and helped to reveal a desire for such fora and working meetings to continue, along with dedicated ESA initiatives to move the innovation agenda forward. To satisfy that need, the Blockchain Workshop will be followed by: a special session at the ESA 2019 Living Planet Symposium, to be held 16 May 2019 in Milan, to increase awareness, communicate opportunities and build support for the implementation of the steps proposed in this White Paper; and a second edition of Blockchain Workshop at the 2019 **Φ**-Week.

4.2.4 Regulatory, legal and ethical issues

Blockchain and distributed ledgers are currently subject to legislation instruments at EU and national level.

In October 2018 the **European Parliament issued a resolution on 'Distributed ledger technologies and blockchains: building trust with disintermediation**' to step up the EU regulation in this field.[29] The elements of this document are aimed to resolve the challenges of legal protection and competitiveness related to the use of distributed ledgers, the principle of technological neutrality, and fair competition among players. It also highlights various usages of DLTs in finance, including implications for e-commerce, energy, healthcare, education, and creative industries (e.g. for the management of copyright or patents), as well as in public sector (e.g. digitalisation and decentralised management of public databases, licensing, certification, etc.).

Moreover important questions of related to **data privacy on blockchain**, are increasingly at the centre of many legal considerations, in particular issues related to the 'right to be forgotten' (vis-a-vis the irreversibility and immutability of data in a blockchain), and the Privacy by Design approach required by the EU GDPR. They emphasise the need to develop GDPR-compliant blockchain use cases, and the fact that many of the GDPR's requirements are easier and simpler to interpret and implement in private, permissioned blockchain networks than in public, permissionless networks. [30]

Finally, there are concerns over the **environmental considerations** of running large-scale computing infrastructures. It has been reported, for example, that the computing power required to keep the Bitcoin network running consumes as much energy as is used by 159 of the world's developing nations taken together.[31] While the blockchain industry is currently switching to less energy-demanding solutions, the total energy consumption of all digital infrastructure around the world will only increase. The ICT infrastructure already consumes 10-15% of total energy production. Research suggests that data centres will be one of the biggest energy industry users on the planet, reaching 20% of all available electricity in the world by 2025. The chief requirement here is therefore to ensure that any applicable data centres and infrastructures underlying ESA projects will take into account and contribute in a positive way to this energy future (i.e. by applying energy-efficient processing steps or relying on green and renewable energy sources).

4.3 Scoping the opportunity

There is still no existing cohort of users of DLT in the EO sector (and vice versa, there is not much evidence of focussed interest from the DApp community in adopting EO solutions into their digital value chains). This implies that there are no legacy players, and therefore an opportunity to be at the cutting edge of the technology, defining best practice for the community, especially given the fact that Europe is a global leader in EO and has a high stake in its data production pipelines.

4.3.1 Defining an approach

The use cases and research topics highlighted in this section are based on initial recommendations defined during the 2018 Blockchain Workshop as suitable for testing the feasibility of DLT solutions, and for initial user uptake assessment. Each of those cases and topics now needs to be specified in terms of resources, requirements, design and technical platform building solution, implementation and success criteria. The list of recommendations emerging from these pilot projects should be updated on a regular basis at the community meetings and via industry consultations. In this early phase, the primary objective will be to share findings and analysis of what went right, what needs to be improved and where to move next.

4.3.2 Technology scouting

Proactive scouting of emerging technology is the key to discovering innovative solutions. Technology scouting processes involve early identification, exploration and scientific assessment of promising new R&D avenues, for possible technical follow-up in ESA R&D programmes.

It is not currently clear whether DLT is on a 'cure' trajectory or is a bubble, and it remains to be seen whether it will reach maturity. Nevertheless it is useful to keep in mind that, even though the majority of existing DLT use cases seem remote from the EO community's day-to-day activities, active review of the existing blockchain initiatives and analysis of the uptake in other industry sectors will provide valuable practical insights and lessons learnt.

4.3.3 Active prototyping

Active prototyping requires consideration of low levels of TRL (Technology Readiness Level), i.e. TLR1-3. At the same time, the turnaround of pilot projects should be high, to reflect the fast pace of growth in the DLT sector. The design process should therefore involve rapid sketching and prototyping methods. Testing ideas with users should be encouraged to flesh out and evaluate the value proposition.

4.3.4 Field testing

A substantial number of blockchain application prototypes have so far been implemented in non-EO sectors, and a far smaller number developed specifically to address the needs of the EO community. We need to move from prototype to field test to evaluate the potential for implementation at scale. There are many implementation avenues available to move into (low cost) field tests, although they require buy-in from users. This entails building trust and transparency among developers, and the shared goal of jointly delivering a 'feasibility check' of the value proposition. The Active Prototyping phase should reveal an exact need for such further developments and field testing.

5. ROADMAP

When it comes to designing a roadmap for distributed ledgers in selected EO priority domains, we should distinguish between

- Conceptual applications of DLTs
- Business potential
- Implementation feasibility.

The following sections define the topics proposed for research and active prototyping, as well as field testing on a limited scale, with the specific aim of assessing and validating the value proposition.

5.1 Defining High Level R&D (Applied Research agenda)

Blockchain is intended to become a foundation for many different, customisable and off-the-shelf solutions for data management, processing and sharing. Since the functional value of DLT outside of cryptocurrencies has yet to be proven, it is of paramount importance to focus on the functional goals and challenges that the EO community faces.

An initial set of blockchain concept projects, as well as a review of major European initiatives in this field, has provided useful insight into possible applications. A number of open research questions were revealed, exploration of which can help to draw out conclusions about the implications of blockchain-based data structures for a number of topics, including.

- EO data standards
- Incentivisation in community collaborations
- Governance of distributed processing in cloud infrastructures
- The expansion of EO platform functionalities
- Future distributed processing scenarios.

The preliminary list includes the following research themes:

Research theme 1: **Emerging Data Standards** including protocols and standards helping to power IoT devices, apps and applications including W3C Standards on the Web of Things. Their role is to reduce fragmentation, and increase the interoperability of sensor networks, as well as to introduce new layers and data structures for industry-specific protocols to deploy spatial data on blockchain via initiatives like FOAM Open Protocol.

Research theme 2: **Incentivisation**. This research theme is aimed at exploring what might encourage EO communities to cooperate and create value using blockchain enabled infrastructures, and assessing the relative costs and benefits. For example the use of incentives and cryptography are key to design new kinds of systems, applications, and networks for EO data curation and labelling services, among others.

Research theme 3: **DLT infrastructure and governance of distributed processing in cloud infrastructures**. Collaborative ecosystems built on blockchain data structures need to consider governance issues, such as shared databases, ownership of input data, products or software elements, identities (signatures) of contracted/ trusted partners, their shared responsibility, pricing and business models, and the framework for collaboration with value exchange and revenue sharing.

Research theme 4: **Blockchain as a Service (BaaS)**. The BaaS concept is a potential solution for the creation of private, public and consortium-driven blockchain environments, built in industry-leading cloud environments, which can offer automated scalability. The BaaS uptake is important because it may accelerate testing of applications and development of the Smart Contract concept. Such a standardisation effort, although useful and potentially effective at scale, may nevertheless result in the centralisation of certain solutions in the hands of the so-called 'big tech' companies. Given Europe's interest in developing independent cloud infrastructures, including for EO data handling, and application development in line with European innovation strategy for EO, all such developments need to be taken into account here. This research theme is aimed at exploring the specificities of European EO capabilities and defining enabling conditions, threats, opportunities, benefits and implications for a common architecture for potential BaaS implementation in European EO clouds.

Research theme 5: **Autonomous systems and onboard processing in space**. Addressing the technical challenges of advanced onboard processing is highly applicable to the future of efficient data product development, and information extraction systems, installed onboard EO satellites. This research theme is aimed at exploring the deployment of robust onboard processing chains, ensuring their integrity, reliability, immutability, and compatibility with communications architectures with ground segment and space segment assets, for applications, such as automatic event-based triggering or self-optimising, and self-configuring automation of processing and monitoring tasks.

5.2 Use Cases

Responding to operational needs requires the identification of real industry challenges in relative to the underlying building blocks of the EO sector. This can be, for example, data and product life cycle management and control, certification of data and software value chains, data interoperability and data fusion, data security and personal/sensitive data protection, protection of intellectual property rights, incentivisation in crowdsourcing and citizen science, and potential e-commerce solutions (i.e. Smart Contracts).

The list of DLT use cases in the EO sector provided below is scoped around identified needs, and based on the initial evaluation of relevance to EO as suggested by the community during the 2018 Blockchain Workshop. However, it is not exclusive or exhaustive. Some of the topics are already under research and development via small-scale exploratory activities and will yield the first results in 2019. What will define the success criteria for real industry applications is the ability to demonstrate demand from users, willingness of uptake, and feasibility of the implementation at scale. A suite of user-driven projects should initiate **feedback loops** concerning the utility of DLT for the EO industry and service development. They should also **draw conclusions** and a way forward for any potential larger-scale implementation. The following domains have been identified as a priority:

Use Case 1: **EO data and information product integrity, traceability, automated certification and auditability.** The use case includes organising, arranging and tracking distributed processing in the cloud, and building trust in algorithms and data processing chains, in particular the authentication of provenance and certification of data and processes. For the Sentinel Products Life Cycle this involves:

- The use of blockchain data structures to validate EO data and metadata (data acquisition time/date etc.) provenance, by providing a trust anchor that any third party can use in case of a dispute
- The use of blockchain data structures to verify the steps of processing, archiving and dissemination of the data from the Sentinel Core Ground Segment to the end-users
- The use of blockchain data structures to give the operators of the Copernicus Space Component Data Access System means to audit the Copernicus products archive.

Use Case 2: **Supply chain tracking in the EO upstream segment.** The use case concerns the analysis of existing frameworks for using blockchain-based registers for COTS supply management, as used already on a pilot basis in other industry sectors (i.e. automotive). This is in particular for parts authentication, which can achieve greater transparency between manufacturers, sellers and finance services, which can in turn expedite the processing of export/import and banking documentation, and ultimately reduce the settlement period between different parties in the supply chain.

Use Case 3: **Digital Identity solutions.** The use case includes the analysis of international standardisation efforts led by industry for the easier exchange of digital identity credentials between different entities/devices in the decentralised ecosystem, as well as European initiatives such as eIDAS (electronic IDentification, Authentication and trust Service) that may be integrated with blockchain to provide digital data representation and trusted identity frameworks for use in decentralised networks.

Use Case 4: **EO data access and trading**. The use case includes the exploration of novel concepts for EO data digital licenses which are programmable and self-executing based on the user's profile, identity or tasks undertaken in the online/platform environment. They may result in the development of EO data rental and trading schemes based on tokenisation of assets.

Use Case 5: Intellectual Property Rights (IPR). The use case reflects DLT applications for copyright protection. Existing examples from other industry domains indicate that authors and creators can publish works on blockchain creating a quasi-immutable record of initial ownership, and encode smart contract functionality to license the use of their works. For the EO sector the key point of value-adding interest is the ability to register copyright products in online registers, track the use of IP elements (ie. software and data products) and develop new ways of attributing use, and exchange of value for the use of copyright-protected content.

Use Case 6: Incentives in community collaborations. Blockchain general utility is primarily revealed in situations when parties that do not trust each other have to work and collaborate together. This use case is based on blockchain-specific functions that can enhance trust frameworks among the participants in the collaborative networks. Blockchain encourages community collaboration without intermediaries, while protecting the ownership of encrypted/shared data, or software elements, and providing accountability for its use, and maintaining integrity of the resource pool. Devising frameworks for interacting among network participants via a tokenised system can also facilitate the ingestion of verifiable data sources to the pool of shareable resources, and revenue sharing schemes.

Use Case 7: Digital representation of assets for emerging DApps (Distributed Applications) services and Smart Contract execution. This use case is to demonstrate the role of EO in blockchain applications; in particular how EO can bridge and connect the physical environment to digital ledgers, and support the formulation of structured data flows in a variety of asset management, risk management, environmental management, logistics or insurance domains (to name a few).

5.3 Milestones

The desired outcome for the next steps includes reaching the following Milestones (M).

- DLT applicability identified, tested and verified with users (prototyping Phase 1)
- New use scenarios of EO data unlocked and documented
- New uses of DLT unlocked and documented
- Lessons learnt and shared with the community
- Bridge between EO and DLT communities in place and links actively cultivated (via joint events and cross-fertilisation)
- Rationale for dedicated actions with DLT R&D, private and startup ecosystems accepted by EO stakeholders and carried out in harmony with national and European strategies
- Positive feedback of ESA objectives and ESA leadership on behalf of the community.

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ANNEX 1

Agenda and Participants

2018 ESA Blockchain Workshop

15 november, 2018 | ESA–ESRIN | Frascati (Rome), Italy

Venue: ESRIN, Φ-Lab Facility

09:00 - 09:15
Welcome & introductions
Sveinung Loekken (ESA), Anna Burzykowska (ESA), Andreas Vollrath (ESA)

09:15 - 09:35
Space-based ‘digital twin’ of earth brings affordable EO insights to the other seven billion of us
Carsten Stöcker, Spherity

09:35 - 09:50
Evolving EO data trading by means of the blockChain technology
Cristoforo Abbattista, Planetek

09:50 - 10:05
NGOs and satellite imagery: blockchain use case
Robert Keenan, Consensys

10:05 - 10:20
KSI blockchain for EO data integrity
Andreas Sisask, Guardtime

10:20 - 10:35
Onboard AI for nanosat cluster: distributed computing power in space with permanent earth observation and onboard image analysis
Maxim Prasolov, Neuromation

10:35 - 10:50
CEVEN: how blockchain-based geo-smart contracts fuel the IoT
Yashar Morandi, CloudEO

10:50 - 11:00
IoT over satellite: possible application of blockchain technologies
Matteo Merialdo, Rhea

11:00-11:15 – Coffee Break

11:15 - 12:00

Data, AI, and tokens: ocean protocol

John Enevoldsen, Ocean Protocol

11:30 - 11:45

Sensors, automation, and oracles in blockchain platforms

August Botsford, Chromaway

11:45 - 12:00

Satellite imagery and blockchain technologies to upscale natural conservation programmes

Alastair Marke, BCI

12:30-13:30 – Lunch Break

13:30 - 13:50

DLT in monitoring and analysis of food safety and food sustainability data

Genevieve Leveille, AgriLedger

13:50 - 14:05

Blockchain is not the technology to create sustainable supply chains, but satellite remote sensing is

Ernst Thomas Kuilder, Satelligence

14:05 - 14:20

Beyond the hype: what are useful links between HLT and GSI for smallholder agriculture

Gideon Kruseman, CIMMYT, CGIAR Platform for Big Data for Agriculture

14:20 - 14:30

HeraSpace, future of EO data and the blockchain

Isaac Durá Hurtado, Heraspace

14:30 - 17:30

Breakout into a roundtable working session to provide detailed feedback concerning existing systems and solutions, stakeholders, data domains and information flows.