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Orbit decentralized autonomous organization using blockchain-based consensus mechanisms:
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Orbit Decentralized Autonomous Organization Using Blockchain-Based Consensus Mechanisms

Red Boumghar *,Annalisa Riccardi†,Cesar Guzman‡,Shahzad Ameen§

In applications such as space traffic and disaster response management, public and private capabilities are growing fast. Multiple different stakeholders can create insight; detect and identify events (spacecraft conjunctions, natural disasters). An increase in the number of sources creating these insights lead to confusion for local authorities, operators or any insight users. The situation is so uncertain that the management of risk has lead to costly counter actions to be taken although they are likely to be non necessary. In space traffic management, a collision avoidance maneuver is costly and introduces secondary risks by changing a resident space object (RSO) trajectory and risking potential new conjunctions and eventually more probable collisions. This project, Space DAO (Decentralized Autonomous Organization), sets the base infrastructure to agree on consensus mechanisms to reduce confusion and augment trust in key decision making information. Space DAO nurture the diversity of insight sources and acts as a market place for space insights offering governance power to users as well as data and services providers. It provides an innovative way to computationally define rules for space applications and an exchange for in-orbit and space related services.

I. Introduction

There is a continual effort to increase spacecraft functionalities by incorporating more instruments and resources for storage, computation, and communication bandwidth. Spacecraft tend to become shared resources, like regular components of cloud infrastructure on the ground, which are optimized to automatically adapt to demands for computational, storage, and data transfer resources. To highlight these efforts, the European Space Agency (ESA) recently launched an innovative campaign for the Cognitive Cloud as the intelligent extension of ground cloud infrastructure to orbit. Adding cognitive functions means bringing the system to a higher level of autonomy and awareness with the challenge of agreeing on decisions among multiple agents (machines and humans) and detecting resources need to plan actions automatically.

Democratization of edge computing is moving part of these autonomous decisions to happen on-board. While the size and number of data sets grow and the complexity of decisions augment, less efforts have been made to find consensus mechanisms and suitable ecosystems to achieve the necessary agreement within a satellite network governed by multiple authorities with different planning tools [1].

Supported by the ESA Cognitive Cloud campaign, the Space DAO (Decentralised Autonomous Organization) project objective is to investigate how information providers and data processing contributors can interact by using blockchain consensus mechanisms [2] and how this could increase trust in the information layer and have impact in the action layer. It also shows how they can apply to an ecosystem of federated networks of Earth-orbiting satellites (systems of systems) where all actors interact within a decentralized autonomous organization, with no required trusted central authority [3]. We applied our blockchain DAO approach to respond autonomously in two use cases, the first one for Space Traffic Management (STM), and the second one for Spacecraft Resource Management (SRM) in the applied case for disaster response support.

The following section shortly introduces the spacecraft resource management in disaster response management

II. Disaster Response Management (DRM)

The numerous space assets dedicated to Earth Observation constitute a cloud of resources and services that could be shared across users thanks to a distributed management consensus. This need grows when operators want to provide

*Parametry.ai, red@parametry.ai
†University of Strathclyde, annalisa.riccardi@strath.ac.uk
‡Vision Space Technology Gmbh, cesar.guzman@visionspace.com
§Parametry.ai, shahzad@parametry.ai

smarter and autonomous services and when, at the same time, interacting and associating themselves with a larger pool of users and risk assessment stakeholders becomes the core of the business. The International Charter Space and Major Disasters (the Charter) is a good example of an initiative that could benefit from automated processing requests and access to a distributed large community of in-orbit or on-ground services and data providers. The outcome could reduce the response time from currently 1.5 days to a few hours over the 40 disaster activations they usually get every year. In order to take advantage of expanding on-board intelligence, such initiative shall create bridges among more actors to enter the markets of on-board satellite imagery processing, AI/Edge APIs need to be verified against their performance thanks to external test datasets, in a fast and autonomous way. There are different roles that are part of an ecosystem in the example of major disaster support:

- Local authorities as requesters of the disaster support;
- Satellite mission operators or data contributors;
- Request managers and operators, they prepare the data and risk maps;
- Processors who provide cognitive capabilities to the network;
- External validators who make sure processors' output is explainable and valid.

The blockchain approach to this problem brings opportunities to use first-party information instead of middlemen third parties. It also enables transparent decentralized governance, in a trust-minimized environment (meaning where trust is not an issue as digital contracts set the conditions).

For both applications, the context is already decentralized in terms of governance but less in terms of decision making, while the need for a large amount of expertise is reduced by the service-oriented architectures, a high level of trust is still needed on decision makers. Blockchain, as a technology, offers a great opportunity to rethink how trust is managed by providing a middleware environment to encode business logic and leave less room for uncertainty; data streams from suppliers are verified and decisions are reviewed and assessed in predefined consensus logic. Blockchain offers a coherent single source of truth for transparency of operations while protecting eventual intellectual property rights or confidential assets.

The project, built as a global community, paves the way to a new kind of ecosystem for multi-constellation (multi-stakeholders) spacecraft as a service (MCSaaS) for in orbit applications such as automated disaster response as well as, by extension, multi-asset deep space exploration missions.

III. Space Traffic Management (STM) Decentralized Application

A. Current Issues in Space Traffic

Managing space traffic to guarantee the safety of the orbital assets and the long-term sustainability of low-Earth and medium-Earth orbits is still a major unsolved global challenge. There is an increasing orbit occupation from public and private operators. Moreover, the growing civil capabilities in space situational awareness, pushes trust on conjunction and collisions alerts to shift towards third party claiming capabilities. The benefits of blockchain in this domain are multiple.

STM has already evolved towards more autonomous systems [4] where NASA invites stakeholders to participate in a system architecture that connects autonomous services via APIs, nevertheless, this autonomy is still in the experimental phase. The typologies of stakeholders are well identified as data and information suppliers, service suppliers, national and international authorities.

Current approaches rely on peer-to-peer ad-hoc interactions among stakeholders, of mundane manual tasks such as risk analysis and mitigation actions. The situation is worsened by the:

- Lack of trust among some operators, exacerbated by geopolitical conflicts;
- Lack of effective international coordination;
- Lack of awareness and verifiability of the risk;
- Lack of reliable and up-to-date collision risk forecasts;
- Different understanding of what is an acceptable level of risk;
- Lack of international standards and policies (right of way);
- Lack of technical and human resources by many of the operators to plan and perform collision avoidance manoeuvres;
- Lack of accountability.

The EU SST Collision Avoidance (CA) service, implemented in the scope of the EC Decision No 541/2014/EU, is a

first step in the right direction, nevertheless it is currently limited to conjunction analysis and lacks the global reach and transparency.

The proposed application in this domain explores the use of blockchains distributed consensus algorithms and distributed in-orbit processing capabilities to help automate space traffic management, increase its transparency, and guarantee its integrity, conformity and compliance. The application addresses both the analysis of the risk, and coordination of risk mitigation actions, including the planning and execution of Collision Avoidance Manoeuvres (CAM).

B. Automated consensus and maneuvers negotiations

The workflow for the space traffic DApp (decentralised application) depicts how the space traffic management works in reaching consensus about conjunctions, using the CDM (conjunction data message) as information artifact. Phase 1 (Figure 2) consists of determining, with best confidence, what is the current consensus on a conjunction alert. Several providers currently independetly track conjunctions and are able to provided updated conjunction data message (CDMs). These CDMs can be clustered by event for comparison. A Bayes fusion mechanism permits to establish a consensus not only based on CDMs input but also on each providers' trust model. These models serve to track a aggregated confidence for each provider.

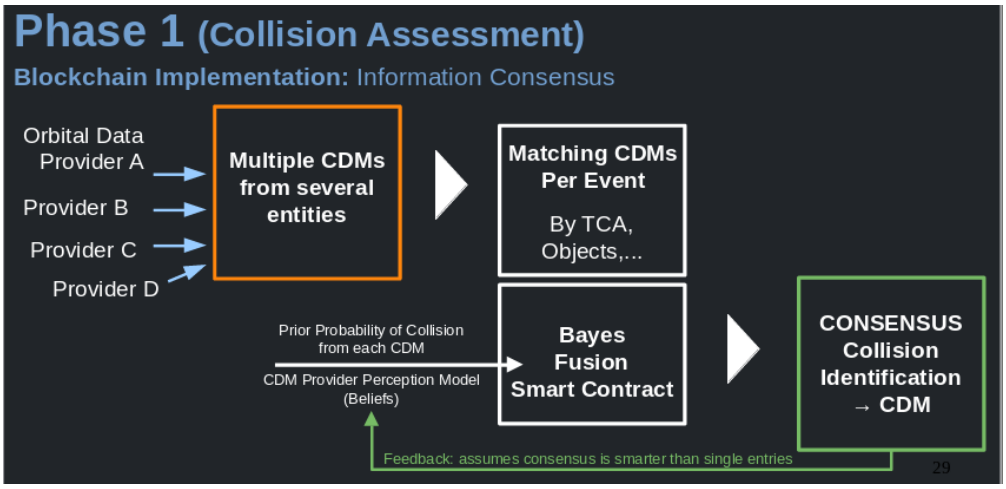

Fig. 1 Phase 1 - Consensus on Space Traffic information

The consensus creation allows space operators to gain trust augmented conjunction information and to be able to maintain a dynamic judgement of data providers that could be as granular as per resident space object pairs. So the network maintains a knowledge of how good data providers perform in general and for each monitored asset, enabling to take their data into account with various confidence levels.

Phase 2 (Figure 2) consists in automating the decision to maneuver according to pre-agreed smart contract that can use very rational rules or pre-agreed conditions between the two (or more) operating entities involved in the conjunction.

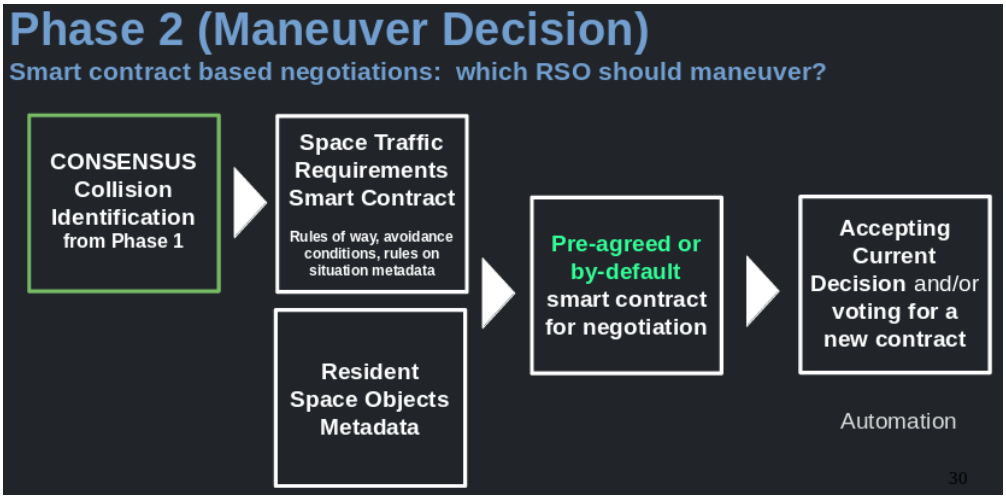

Fig. 2 Phase 2 - Maneuver negotiation automated contracts

Resulting decisions can be directly ingested by the various mission control systems and are issued as information. Responsibility to engage actions from the network decisions still remains on the operators. The network acts as a registry and records all activity in order to be able to create incentives to act for a safer space which can include rewards for those who do.

IV. Platform for decentralised space services

The first architecture of the DAO was designed and implemented thanks to the support of an innovation project from the European Space Agency [5]. The created prototype will be soon available on `https://spacedao.ai` and run on a private testnet.

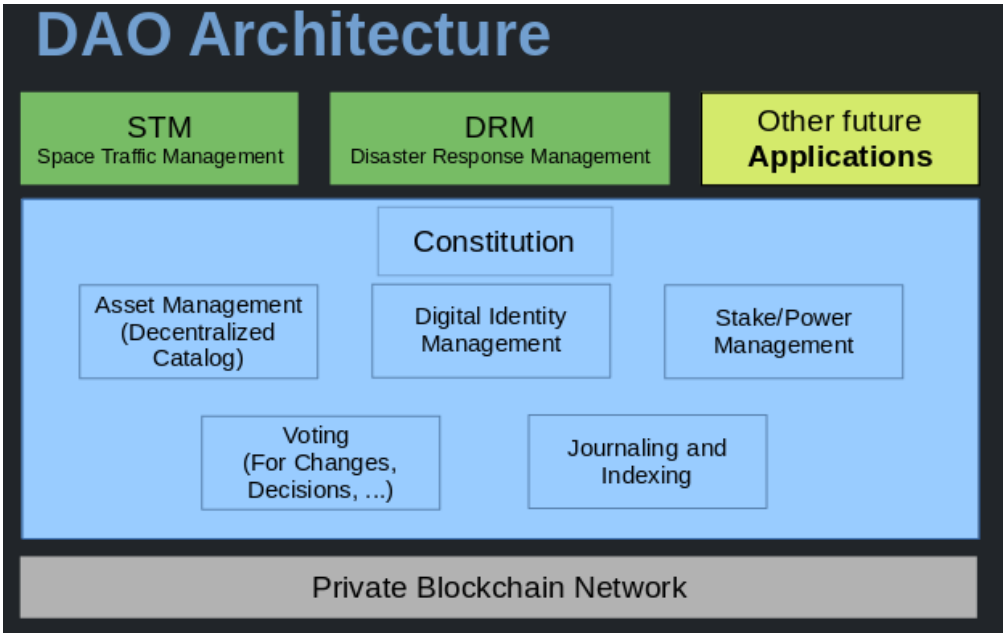

Fig. 3 DAO and DApps architecture

The impacts, on the ecosystem of in-orbit and from-space services, from both designed decentralized applications (STM and DRM) are notable. Space traffic is already shaped as a global and decentralized ecosystem; there are many

different monitoring public and private companies, and the same applies for the operations side. As some providers in space situation awareness (for space traffic management) are growing in size and importance, the risk of centralisation grows (monopoly position, unverifiable manipulation of information, and concurrent incentives with other governments).

The initial contributors are two private companies (Parametry.ai, and Vision Space Tech GmbH) and the University of Strathclyde. Further collaborations are nurtured thanks to the transparency of the project. All smart contracts and applications are developed under the Open Source License GNU LGPLv3 and are available on the project repositories.

Another important impact is that the network allows stakeholders to propose new rules of space and allow them to be recorded as smart contracts so that further usage can be made of them providing regulators feedback before rules are enforced. Space DAO can be used as a database and business logic infrastructure for digital twin simulation engines; this offers the capacity to test what would happen, in our vital and commonly shared Earth Orbit, when rules are changed.

V. Conclusion

In applications like space traffic management, the community is currently and independently expressing rationales for decentralization and trust augmented information even at the highest level in the industry (see quote in figure 4). There is urgency to manage space traffic correctly and responsibly, to avoid uncontrolled atmosphere re-entry now and to avoid future space congestion issues. In this decade, one out three uncontrolled reentry will very likely end up crashing on a city, with high potential of casualties [6]. The Kessler syndrome is not close to happening yet but there is a chain of reactions we can avoid right now by more global and transparent agreements and organized collaborations.

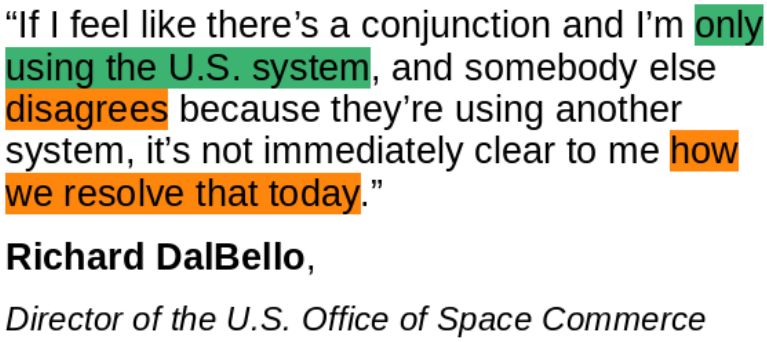

Fig. 4 Words captured from Richard Dalbello speaking at the annual conference of the Global Network on Sustainability in Space (GNOSIS) (30th November 2022). Extract from `https://spacenews.com/growth-of-ssa-systems-could-create-problems-for-satellite-operators/`

Space DAO is in active development and the community of users and contributors is growing fast. Empowered stakeholders of Earth orbit can make valuable and constructive proposals to interact with each other and bring global consensus in how this is done. The professional open and neutral aspects of the project are crucial for disintermediation and in order to set trust in a code that can be tested, reviewed and audited thanks to modern DevSecOps concepts and strong open source licensing [7]. Multiple space operators and flight dynamics engineers have already expressed their interest and SSA providers are already providing the first data stream to the network, benefiting from its automated market place economics. In parallel, the discussion with regulatory bodies and space lawyers or academics influencing space traffic rules is maintained to find the right way of interactions: a DAO is a vector of propositions that can be voted upon then implemented and tested.

Space DAO offers an innovative way to align the various SSA solutions, keeping in mind inter-governmental negotiations and peace keeping transparency. Everything one needs to know is on the main website at `https://spacedao.ai` and the source code for Space DAO project is open source and is licensed under the LGPL3 license `https://gitlab.com/parametry-ai/space-dao`

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