RNI: DELENG/2005/15153
Publication: 15th of every month
Posting: 27th/28th of every month at DPSO

No: DL(E)-01/5079/2020-22
Licensed to post without pre-payment U(E) 28/2020-22
Rs.150

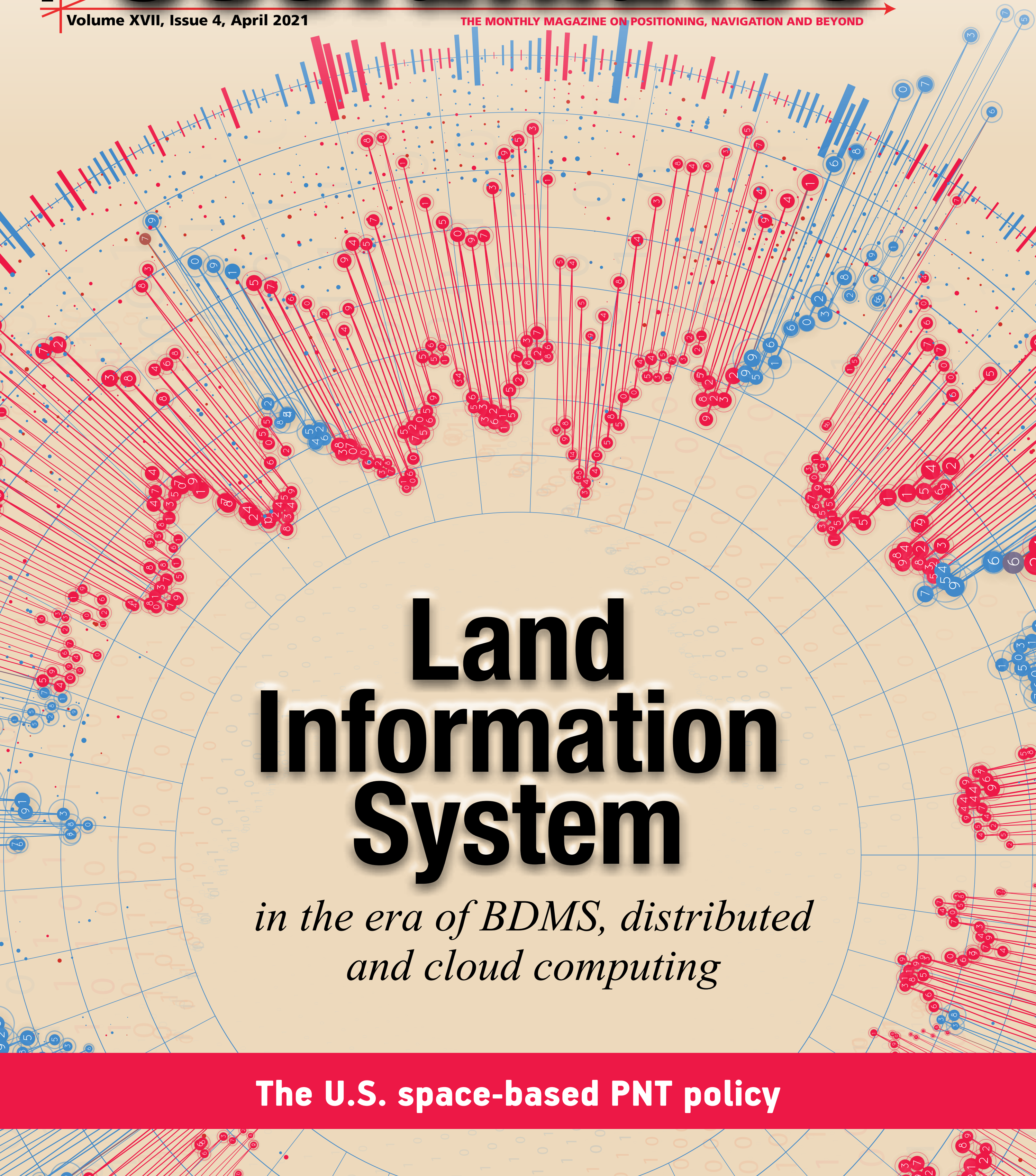
ISSN 0973-2136

www.mycoordinates.org

Coordinates

Volume XVII, Issue 4, April 2021

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND



Land Information System

in the era of BDMS, distributed and cloud computing

The U.S. space-based PNT policy


SBG SYSTEMS
0.05°
ATTITUDE
0.02°
HEADING
1 cm
POSITION
The Smallest Dual Frequency
& Dual Antenna INS/GNSS
» RTK Centimetric Position
» Quad Constellations
» Post-processing Software
NEW ELLIPSE-D
Ellipse-D
RTK Dual Antenna
Ellipse-N
RTK Single Antenna
OEM
RTK Best-in-class SWaP-C
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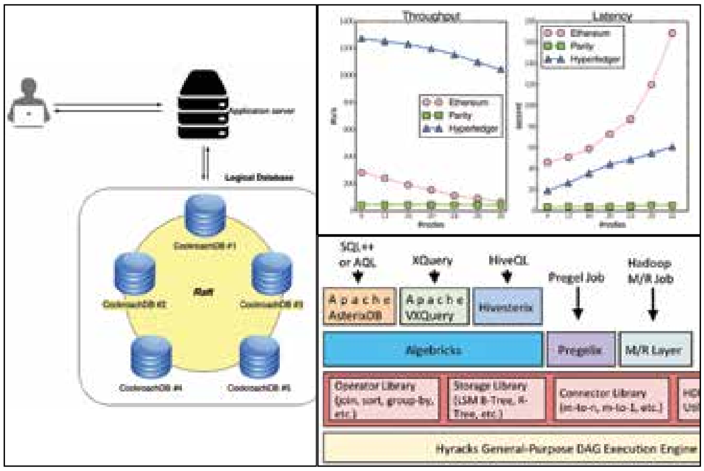

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Columns

This issue has been made possible by the support and good wishes of the following individuals and companies
Brent Jones, and Zdravko Galić, Labsat, SBG System, and many others.

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Annual subscription (12 issues)
[India] Rs.1,800 [Overseas] US$100

Printed and published by Sanjay Malaviya on behalf of Coordinates Media Pvt Ltd
Published at A 002 Mansara Apartments, Vasundhara Enclave, Delhi 110096, India.
Printed at Thomson Press (India) Ltd, Mathura Road, Faridabad, India

Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

This issue of Coordinates is of 40 pages, including cover.

Devastation

When it hit, it hit hard.

The second wave of Covid-19 in India.

Millions infected, hospitals overwhelmed, crumbling health infrastructure, …

Many were struggling – for doctors, medicines, beds in hospitals, oxygen cylinders, cremations,…

With no or little support.

The best was that medical fraternity scrambled to do whatever it could,

And many and many volunteered to help, to serve, to donate, ...

The worse was the profiteering, as a few throve on the crises,

And the worst was the apathy and the indifference from an unapologetic system.

It was all about disease and deaths.

It was devastating.

Bal Krishna, Editor
bal@mycoordinates.org

LIS in the era of BDMS, distributed and cloud computing: Is it time for a complete redesign?

In this paper, we present the main features of a new class of emerging DBMSs, namely NoSQL and NewSQL, from the data management perspective with a particular focus on distributed computing and share-nothing architecture

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Abstract

For over four decades, traditional relational database management systems (DBMS) have been the leading technology for data storage, retrieval and management. However, they were designed in a different hardware and software era and are facing challenges in meeting the performance and scale requirements of distributed data-intensive applications, including Big Data. These *traditional* database management systems are not designed to take advantage of distributed and cloud computing. They support vertical (*scale-up*) rather than horizontal (*scale-out*) scalability, which is more common in distributed systems and applications. Due to increasing needs for scalability and performance, alternative systems have emerged: NoSQL and NewSQL database management systems.

Distributed computing and share-nothing architecture became very popular during the last decade. At the same time, cloud computing has emerged as a computational paradigm for on-demand network access to a shared pool of computing resources. Proliferation of open-source and commercial distributed data management systems and cloud computing platforms makes building distributed, data-intensive applications and systems in the land administration domain easier than ever before.

In this paper, we present the main features of a new class of emerging DBMSs, namely NoSQL and NewSQL, from the data management perspective with a particular focus on distributed computing and share-nothing architecture. We also briefly present a simple taxonomic classification of DBMSs for choosing a DBMS in building land information systems (LIS) and applications, and two LIS prototypes built on NoSQL BDMS and NewSQL DBMS.

Introduction

The majority of the existing land information systems (LIS) are dominantly online transaction processing (OLTP) systems, built on mission-critical (object-) relational database management systems (DBMSs) such as Oracle, Microsoft SQL Server, IBM DB2, MySQL, and PostgreSQL. Modern general-purpose OLTP database systems include a standard suite of features: a collection of on-disk data structures for storing relational tables row-by-row, heap files and B-trees for indexing, support for multiple concurrent queries via locking-based concurrency control and ACID[1] transaction properties, log-based recovery, and an efficient buffer manager. These features were developed to support transaction processing in the 1970's and 1980's, when an OLTP database was many times larger than the main memory, and when the computers that ran these databases cost hundreds of thousands to millions of dollars (Stonebraker & Cetintemel, 2018).

All these systems were architected when hardware characteristics were much different than today: (i) processors are thousands of times faster; (ii) memories are thousands of times larger; and (iii) disk volumes have increased enormously. However, the bandwidth between disk and main memory has increased much more slowly. Surprisingly, this relentless pace of technology didn't dramatically affect the architecture of database systems – the architecture of most DBMSs is essentially identical (Stonebraker, et al., 2007). Furthermore, database has been the least scalable component in application architectures. In general, the last four decades of DBMS development could be summarized as *"one size fits all"*, reflecting the fact that the traditional DBMS architecture has been used to support data-intensive applications in different domains and with widely varying capabilities and requirements.

The modern computing environment is largely distributed – enterprises and institutions have geographically distributed and interconnected data centers, forming distributed systems. However, *traditional* DBMS are not designed to take advantage of distributed and cloud computing. They only support vertical *(scale-up)* rather than horizontal *(scale-out)* scalability, which is more common in distributed systems and applications. What's needed is a DBMS that scales-out linearly and limitlessly by adding new commodity servers to a shared-nothing DBMS cluster.

Land administration (LA) agencies often throw additional CPUs and memory at database servers to get more power from these systems. Standard approaches to vertical scalability are costly, requiring expensive hardware and DBMS upgrades, and also add development complexity, and increase overhead and maintenance costs. The crucial problem with vertical scalability is that the cost growth is not linear: a machine with double as many CPUs, RAM and disk capacity as another, usually costs much more than double as much, but can't handle double the workload. Therefore, this architecture makes it complicated to build distributed databases that deliver the expected resilience, consistency and maintainability.

The work presented in (Bennett, Pickering, & Sargent, 2018) and (Bennett, Pickering, & Sargent, 2019) is one of the first systematic and comprehensive research synthesis that was undertaken to get a global review of the uptake and impact of non-relational DBMS and blockchain on the land administration sector. The authors found that recent developments in data management technologies and systems appear to be under-exploited within the LA domain. They correctly concluded that whilst uptake of non-relational DBMS and distributed DBMS is occurring, scaled uptake is much slower than anticipated, and to a significantly lesser degree than in other sectors.

In this paper, we go one step further and present the main features of a new class of emerging DBMSs, *from the data management perspective* with a particular focus on distributed computing/systems and share-nothing architecture. Distributed computing/systems[2] and share- nothing architecture became very popular during the last decade, including many *Big Data* processing platforms/frameworks with scalability and fault tolerance capabilities. They use large amounts of *commodity hardware* to store and analyze big volumes of data in a highly distributed, scalable and cost-effective way. These new systems are also optimized for massive parallel data intensive computations (Apache Hadoop (Apache Software Foundation, 2019), Apache Spark (Apache Software Foundation, 2018), Apache Flink (Apache Software Foundation, 2019)) including their extensions and adaptations for spatial and spatio-temporal domain (SpatialHadoop (Eldawy & Mokbel, 2015), GeoSpark (Yu, Zhang, & Sarwat, 2019), MobyDick (Galić, Mešković, & Osmanović, 2017)). This approach is followed by essentially all high-performance, scalable, DBMSs, as well as by the leading cloud service providers: Amazon (DynamoDB), Google Cloud Platform (Spanner) and Microsoft (Azure Cosmos DB).

The rest of the paper is structured as follows. In Section 2 we discuss the main tradeoffs, issues and challenges in traditional DBMSs and blockchain. Section 3 discusses the CAP theorem and its impact on the emergence of NoSQL and NewSQL databases. Section 4 presents a simple taxonomic classification of DBMSs that can be applied for selecting a DBMS in designing and building land administration systems and applications. An overview of cloud computing models and related cloud services are presented in Section 6. In Section 5, we shortly describe our two LIS prototypes based on a BDMS and NewSQL DBMS. Section 7 concludes the paper and discusses future directions.

Traditional DBMS and blockcahin – Tradeoffs, issues and challenges

Traditional DBMSs

Traditional disk-based DBMSs have four sources of processing overhead which limit their scalability (Harizopoulos, Abadi, Madden, & Stonebraker, 2008):

- *Write-ahead logging* – Traditional DBMSs write everything twice; once to the database and once to the log. Moreover, the log must be forced to disk to guarantee transaction durability. Therefore, logging is an expensive operation.
- *Locking* – Before touching a record, a transaction must set a lock on it in the lock table. This is an overhead-intensive operation.
- *Latching* – Updates to shared data structures (e.g. B-trees, the lock table and resource tables) must be done carefully in multi-threaded

environment. Typically, this is done with short-duration latches, which are another substantial source of overhead.

- *Buffer Management* – Data in traditional DBMSs is stored on fixed-size disk pages. A buffer pool manages which set of disk pages is cached in memory at any given time. Moreover, records must be located on pages and the field boundaries identified. Again, these operations are overhead- intensive.

Figure 1 shows the breakdown of instruction count for various DBMS processing components for a transaction from TPC-C[3]. It shows the 93 percent overhead built into a typical traditional/legacy DBMS, and only 7 percent of machine resources dedicated to the task at hand. Designed primarily for data integrity goals, these overheads prevent traditional DBMSs from scaling to meet big data volumes and workloads.

Figure 1. Traditional DBMS transaction processing effort

The limited scalability and availability of the traditional (*share-everything* and *share-disk*) database architectures that has been used in the cloud is caused by a traditional 3-tier architecture: web clients access a data center that features a load balancer, Web application servers, and database servers. The data center typically uses a shared-nothing cluster, as the most effective solution for the cloud. For a given application, there is one database server that runs a DBMS and provides fault-tolerance and data availability through replication. As the number of Web clients increases, it is a relatively easy to add Web applications servers/ machines to take over incoming load and scale up. However, the database server become the bottleneck – adding new database servers would require replicating the entire database, which would take much time (Öszu & Valduriez, 2020).

Blockchain

Blockchain has become a hot, polemical topic, subject to much hype (Ito, Narula, & Robleh, 2017) and criticism (Roubini, 2018). Most of the initial contributions have been made by developers and companies, outside of academic world – academic research on blockchain has recently started. It is popular topic in modern distributed transaction processing, and more recently there has been a growing interest in the database research community to reconcile DBMSs and blockchain paradigms and technologies.

BlockchainDB (El-Hindi, Binnig, Arasu, Kossmann, & Ramamurthy, 2019) leverages blockchains as a storage layer and introduces a database layer on top that extends blockchains by classical data management techniques (e.g., *sharding*) as well as a standardized query interface to facilitate the adoption of blockchains for data sharing use cases. By introducing the additional database layer, the performance and scalability when using blockchains for data sharing can be improved and the complexity for organizations intending to use blockchains for data sharing can be massively decreased.

Blockchain relational database (Nathan, Govindarajan, Saraf, Sethi, & Jayachandran, 2019) is a blockchain platform built on top of DBMS, where block ordering is performed before transaction execution and transaction execution happens in parallel without prior knowledge of block ordering.

ChainSQL (Muzammal, Qu, & Nasrulin, 2018), is an open-source system developed by integrating the blockchain with the database, i.e. a blockchain database application platform that has the decentralized, distributed and audibility features of the blockchain and quick query processing and well-designed data structure of the distributed databases. ChainSQL features a tamper-resistant and consistent multi-active database, a reliable and cost-effective data-level disaster recovery backup and an auditable transaction log mechanism.

Fabric++ (Sharma, Schuhknecht, Agrawal, & Dittrich, 2018) is the performance enhancement of Hyperledger Fabric[4], towards blurring the conceptual lines between blockchain and distributed DBMSs. It is achieved by (i) identifying similarities of the transaction pipeline of

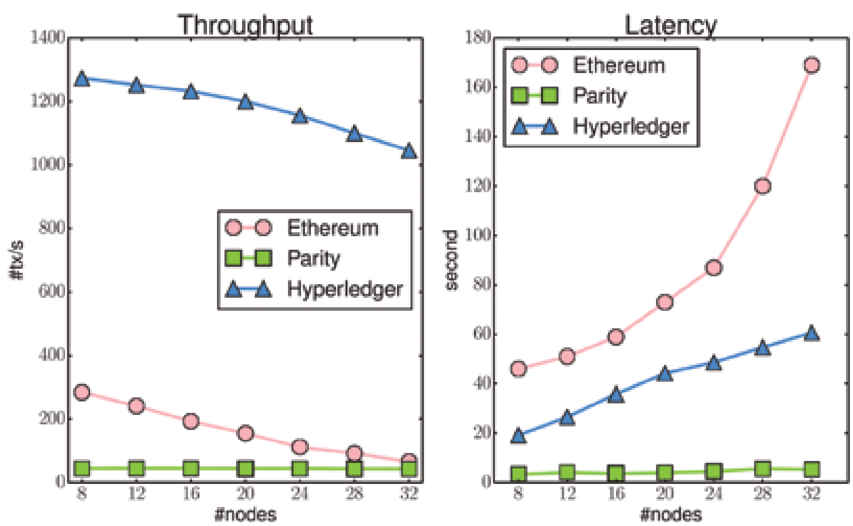


Figure 2. Blockchain performance scalability issues (Dinh, Wang, Chen, Ooi, & Tan, 2018)

However, despite all the hype around the blockchain technology, many of the challenges that blockchain systems have to face are *de facto* fundamental transaction management problems. The main problem lies in *Byzantine fault tolerance*: while distributed DBMSs require a *trusted* set of participants/ nodes, blockchain systems are able to deal with a certain number of *malicious* participants/nodes

contemporary blockchain systems and distributed DBMSs and (ii) by transition of distributed DBMSs technology to the transaction pipeline of Hyperledger Fabric. Fabric++ outperforms the Hyperledger Fabric in terms of throughput of successful transactions by up to factor 3x, while keeping the scaling capabilities intact.

However, despite all the hype around the blockchain technology, many of the challenges that blockchain systems have to face are *de facto* fundamental transaction management problems. The main problem lies in *Byzantine fault tolerance*: while distributed DBMSs require a *trusted* set of participants/nodes, blockchain systems are able to deal with a certain number of *malicious* participants/nodes. Unfortunately, ensuring the Byzantine fault tolerance over all nodes heavily complicates transaction processing: if any node of the network is considered to be potentially malicious, a complex consensus mechanism is required to ensure the integrity of the blockchain system (Sharma, Schuhknecht, Agrawal, & Dittrich, 2018). Under this model, the overhead of concurrency control is much higher. As a consequence, the blockchain is still not being used as a shared database in many real-world OLTP applications. There are two important reasons for this:

1. A major blockchain obstacle is its *limited scalability and performance*. Recent benchmarks results (Dinh, Wang, Chen, Ooi, & Tan, 2018) demonstrate several tradeoffs in the blockchain design that causes big performance gaps between blockchain and DBMSs. The state-of-the-art blockchain systems[5] can only achieve 100s or maximally 1000s of transactions per second (Figure 2), which is often way below the requirements of modern OLTP systems and applications, and also far below what state-of-the-art DBMSs can offer.
2. Blockchain lacks high-level abstractions such as SQL as well as other transactional guarantees like well-defined consistency levels. Similar to NoSQL DBMS, state-of-the-art blockchain systems have proprietary, low-level programming interfaces (aka *smart contract language*) and require application developers to know about the internals of a blockchain to decide on the visibility of updates, which radically reduces developers' productivity.

As confirmed in (Dinh, Wang, Chen, Ooi, & Tan, 2018), the current state-of-the-art blockchain systems are not yet ready (and may never be ready) for mass usage, and there is no other well- established application domain beside crypto-currency. They perform poorly at data-intensive processing tasks being efficiently handled by DBMSs and the performance gap is still too big for blockchains to be disruptive to state-of-the-art distributed and share-nothing DBMSs.

CAP theorem – Its reflections and impact on NoSQL and NewSQL DBMS

Replication is a fundamental concept of distributed systems for achieving availability and scalability – it involves creating and distributing copies of data, as well as ensuring copies remain consistent. Modern distributed data-intensive OLTP applications and systems replicate data across geographically diverse locations to (i) *enable trust decentralization*; (ii) *guarantee low-latency access to data*; and (iii) *provide high availability* even in the face of node and network failures.

The ultimate goal of a distributed system is seemingly simple – it should ideally be just a fault- tolerant and more scalable version of a centralized system. A distributed system should

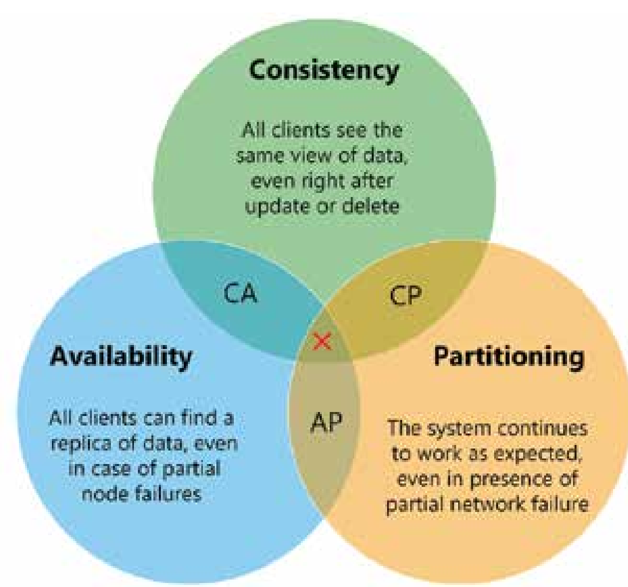


Figure 3. CAP theorem

maintain the simplicity of use of a centralized system, leverage distribution and replication to boost availability by masking failures, provide scalability and/or reduce latency, and its *consistency* (Viotti & Vukolić, 2016).

Recently, there has been considerable renewed interest in the CAP theorem (Brewer, 2000) for database management system (DBMS) applications that span multiple processing nodes.
In brief, this theorem states:

i. There are three properties that could be desired by DBMSs:
   - **C**: Consistency. The goal is to allow multisite transactions to have the familiar *all-or-nothing* semantics, commonly supported by commercial DBMSs. In addition, when replicas are supported, one would want the replicas to always have consistent states.
   - **A**: Availability. The goal is to support a DBMS that is always up. In other words, when a failure occurs, the system should keep going, switching over to a replica.
   - **P**: Partition tolerance. If there is a network failure that splits the processing nodes into two groups that cannot talk to each other, then the goal would be to allow processing to continue in both subgroups.

ii. Any distributed system can have at most two of these three properties (Figure 2).

The CAP theorem[6] famously states that it is impossible to guarantee both consistency (C) and availability (A) in the event of a network partition (P). Since network partitions[7] are always theoretically possible in a distributed system, the modern DBMSs fracture into two paradigms:

- NoSQL that prioritized **A** (availability) – *aka* **AP** DBMS
- NewSQL that prioritized **C** (consistency) – *aka* **CP** DBMS

In other words, the way how a DBMS handles failure determines which elements of the CAP theorem they support:

- NoSQL DBMSs provide mechanisms to resolve conflicts after nodes are reconnected
- NewSQL DBMSs stop allowing updates until a *majority* of nodes are reconnected

In general, consistency refers to the ability of a DBMS to ensure that it complies to a predefined set of rules. However, the set of rules implied by ACID and CAP are totally different – in ACID, the rules refer to application-defined semantics, whereas the C of CAP refers to the rules related to making a concurrent, distributed system appear like a single-threaded, centralized system (Abadi, 2019).

In the NoSQL community, the CAP theorem has been used as the justification for giving up consistency (C). Since most NoSQL systems typically disallow transactions that cross a node boundary, then consistency applies only to replicas. Therefore, this theorem is used to justify giving up consistent replicas and replacing it with *"eventual consistency"*. With this relaxed approach, NoSQL DBMS guarantees that all replicas will converge to the same state eventually, i.e., when network connectivity has been re-established and enough subsequent time has elapsed for replica cleanup. The justification for giving up consistency (C) is such that the availability (A) and partition tolerance (P) can be preserved. Although *eventual consistency* enables high availability, it significantly increases application complexity to handle inconsistent data.

> The CAP theorem asserts that any networked shared-data system can have only two of three desirable properties. However, by explicitly handling partitions, designers can optimize consistency and availability, thereby achieving some tradeoff of all three

NoSQL[8]

As we have seen, the CAP theorem asserts that any networked shared-data system can have only two of three desirable properties. However, by explicitly handling partitions, designers can optimize consistency and availability, thereby achieving some tradeoff of all three. Consequently, designers and researchers have used the CAP theorem as a reason to explore a wide variety of novel distributed systems. The NoSQL vendors also have applied it as an argument against traditional DBMSs (Brewer, 2012). They argued that SQL and transactions were limitations to achieving the high performance needed in modern operational, online transaction processing (OLTP) applications. NoSQL systems forego the ACID (Atomicity, Consistency, Isolation, Durability) guarantees of traditional DBMSs and SQL in exchange for ability to scale out (horizontally) and availability.

However, relaxing or omitting transaction support and eliminating SQL, result in moving back to a low-level DBMS programming interface. Replacing standard ACID with *eventual consistency* or omitting it completely, pushes consistency problems into the application logic where they are much more difficult to solve and manage (Stonebraker, 2012). Application developers are *de facto* forced into handling the *eventual consistency* of NoSQL systems – consequently, NoSQL could be translated into *"lots of work for the application"* (Abadi, 2018).

As already stated, the key feature of NoSQL systems is that they sacrifice ACID transactional guarantees and the (object-) relational model of traditional DBMSs in favor of *eventual consistency (ACID lite)* and other data models (e.g., key/ value, graphs, documents). The two most well-known systems that first followed the NoSQL paradigm are BigTable and Dynamo, followed by their open source clones Cassandra, Riak and HBase, as well as CouchDB and MongoDB. At that time, it was believed that the advantage of using a NoSQL system was to allow developers focusing on the application development, rather than having to worry about how to scale the DBMS.

However, CAP theorem doesn't impose system restrictions in the baseline case. Therefore, it is wrong to assume that DBMSs that reduce consistency (in the absence of any network partitions) are doing so due to CAP-based decision-making. In fact, CAP allows the DBMS to make the complete set of ACID guarantees alongside high availability when there are no network partitions (Abadi, 2012). Therefore, the CAP theorem does not fully justify the default configuration of NoSQL system that reduces consistency, as well as some other ACID guarantees.

NoSQL DBMS are also referred as BASE systems – Basically Available, Soft state, and Eventually consistent (Pritchett, 2008). *Basically Available* means that the database is available all the time whenever it is accessed, even if parts of it are unavailable; *Soft-state* highlights that it does not need to be consistent always and can tolerate inconsistency for a certain time period; and *Eventually consistent* means that while a database may have some inconsistencies at any point in time, it will eventually become consistent when all updates cease

Consequently, both NoSQL vendors and system integrators recognized that NoSQL systems cause application developers to spend too much time on writing code to handle inconsistent data and that ACID transactions increase developers' productivity. Thus, the only option was to purchase a more powerful single-node machine to scale the DBMS up vertically, and to develop the proprietary middleware that supports transactions. Both approaches are very expensive, and this fact actually triggered the design and development of the NewSQL systems (Pavlo & Aslett, 2016).

Therefore, it is not a surprise that many mission-critical enterprises applications, including LISs, have not been able to use NoSQL systems simply because ***they cannot give up strict transactional and consistency requirements***.

NewSQL

The fact that it is extremely difficult to build bug-free applications over NoSQL DBMSs that do not guarantee the strict consistency has resulted in many recently released systems claiming to guarantee C (consistency) and be CP systems. The list of newer systems includes: Cloud Spanner, CockroachDB, FaunaDB, MemSQL, NuoDB, TiDB, VoltDB and YugaByteDB (Abadi, 2018). These systems (and some others, not listed here) preserve SQL and offer high performance and scalability, while preserving the traditional ACID transactions (C in CAP). To distinguish them from the traditional DBMSs and NoSQL, this class of systems is termed as "New SQL". Such systems are equally capable of high throughput as the NoSQL for OLTP read-write workloads, guarantee ACID transactions, eliminate the need for application-level consistency code and preserve the relational model including high-level language query capabilities of SQL.

There are three important reasons for the next generation of LISs to be NewSQL-based (CP), instead of NoSQL-based (AP) systems:

i. NoSQL systems fail to guarantee consistency and result in complex, expensive to develop and maintain, and (often) buggy application code.

The fact that it is extremely difficult to build bug-free applications over NoSQL DBMSs that do not guarantee the strict consistency has resulted in many recently released systems claiming to guarantee C (consistency) and be CP systems

Table 1 Traditional vs. NoSQL vs. NewSQL DBMS

	Pros	Cons
Traditional	SQL ACID	Vertical scaling requires expensive HW, replication, and sharding the database for peak/eventual volumes Do not scale horizontally (out)
NoSQL	Horizontal scalability Availability	Low-level programming interface Lacks consistency guarantees - data management and consistency are embedded in application logic/layer Sacrificed ACID, i.e., strong consistency
NewSQL	Horizontal scalability SQL ACID	

Table 2 Comparison of traditional, NoSQL and NewSQL DBMS

	Traditional DBMS				NoSQL DBMS		NewSQL DBMS	
	Oracle	SQL Server	MySQL	PostgreSQL	MongoDB	DynamoDB	Spanner	CockroachDB
Automated scaling	No	No	No	No	Yes	Yes	Yes	Yes
Failover	Option	Option	Option	Option	Yes	Yes	Yes	Yes
Automated repair	No	No	No	No	Yes	Yes	Yes	Yes
Consistent replication	Option	Option	No	No	Yes	Yes	Yes	Yes
Consensus-based replication	No	No	No	No	No	Yes	Yes	Yes
Distributed transactions	Yes	Yes	No	No	[11]	No	Yes	Yes
ACID semantics	Yes	Yes	Yes	Yes	[12]	[13]	Yes	Yes
SQL	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Open source	No	No	Yes	Yes	Yes	No	No	Yes
Commercial version	Yes	Yes	Option	No	Option	Yes	Yes	Option
Support	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

ii. The availability reduction that is sacrificed to guarantee consistency in NewSQL systems is extremely small, and hardly noticeable for many applications, including LIS.
iii. The CAP theorem is fundamentally asymmetrical: NewSQL systems *guarantee* consistency, whereas NoSQL systems *do not guarantee* availability[9].

Therefore, we believe that the next generation of LISs will remain the OLTP systems, based on a NewSQL DBMS with the following features (Stonebraker, 2012):

i. SQL as the primary mechanism for application interaction.
ii. Strong consistency, i.e. ACID support for transactions.
iii. A nonlocking concurrency control mechanism – real-time reads will not conflict with writes and thereby cause them to stall.
iv. An architecture providing much higher per-node performance than available from the traditional DBMS.
v. A *share-nothing architecture*[10] capable of running on a large number of commodity hardware/machinesA
vi. Automatic replication.

Although primarily designed to support the transactional workloads in enterprise applications (like LISs), NewSQL DBMSs have had a relatively slow rate of adoption, especially compared to the developer-driven NoSQL uptake. The main reason for the relatively slow rate is the fact that decisions regarding DBMS choices for enterprise applications are more conservative than for non- transactional workloads in new Web application (Pavlo & Aslett, 2016). Regrettably, and as already mentioned in (Bennett, Pickering, & Sargent, 2019), scaled uptake in the LA/LIS domain is occurring slower than anticipated, and to a lesser degree than in other sectors.

Comparison of traditional, NoSQL and NewSQL DBMS

Table 1 shows the fundamental differences between traditional, NoSQL and NewSQL DBMS.

An additional comparison of the important characteristics of the typical DBMS systems for each DBMS class is shown in Table 2.

- Automatic scaling – automatic and continuous rebalancing of data between the nodes of a cluster.
- Automated failover – uninterrupted

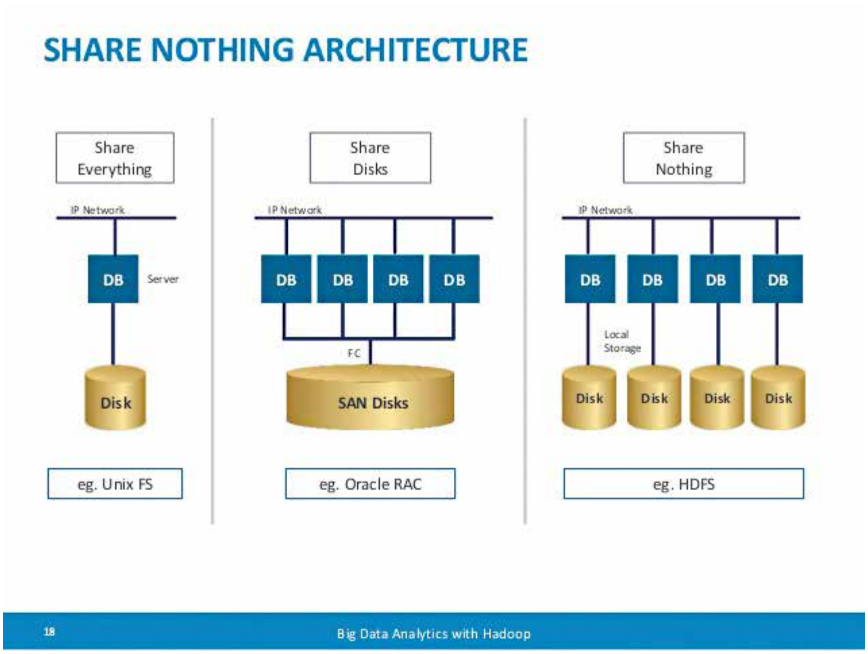


Figure 4. Share-everything, share-disk and share-nothing architecture (Morpheus, 2017)

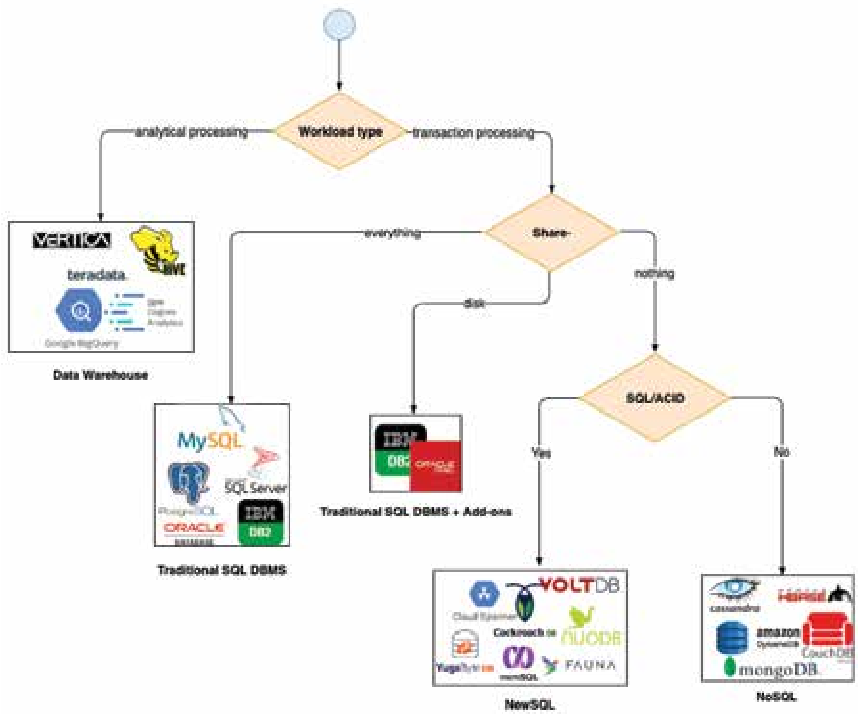


Figure 5. Taxonomic classification of DBMS

availability of data through small-scale and largescale failures, i.e., from server restarts to data center outages.

- Automated repair – automated repair of missing data after failures, using unaffected replicas as sources.
- Strongly consistent replication – once transaction is committed, all reads are guaranteed to see it.
- Consensus-based replication – guarantee that progress can be made as long as any majority of nodes is available.
- Distributed transactions – correctly committed transactions across a distributed cluster, whether it's a few nodes in a single location or many nodes in multiple data centers.
- ACID semantics – every transaction provides atomicity, consistency, isolation and durability.
- Eventual consistent reads – optionally reading from replicas that do not have the most recently written data.
- SQL – high-level DBMS programming interface.
- Open source – source code is freely available.
- Commercial version – enterprise version available to paying customers.
- Support – either limited (free, community-based) or full (paid, 24/7 support).

Table 2 doesn't pretend to be an exhaustive comparison of traditional, NoSQL and NewSQL DBMS, i.e., their capabilities and features – it's rather a general overview of some significant differences and facts relevant for designing and building a new generation of data-intensive applications and systems, especially in the context of distributed and cloud computing. It would be also unfair to conclude that traditional DBMS should not be considered any more in building a new generation of LIS – they are suitable, proven and mature technology in case of share-everything or share-disk architecture and for on-premise, single data center environments. However, traditional DBMS fail to adapt to the distributed, less predictable and high-volume workloads in the cloud deployments.

Also, NewSQL DBMS should not be considered as a panacea for building LIS and other relevant data-intensive applications and systems in the LA domain – these systems/applications should be primarily designed and implemented as (i) *resilient*[14]; (ii) *scalable* and (iii) *maintainable*. *Resilient* systems/applications continue to work correctly even in the face of hardware faults, software faults or human errors. As data volume, traffic volume or complexity grows, they should be *scalable*, i.e., to be able to cope with increased workload. Maintainable systems are *operable*, *simple* and *extensible* (Kleppmann, 2017) – they are simply a prerequisite for *sustainability*. It should be emphasized that simplicity doesn't necessary mean reduction of system/application functionality – it means removing *accidental complexity*, i.e., complexity not inherent in the domain problem, but complexity that arises primarily from the implementation (Ben & Marks, 2006), (Brooks, 1987).

Choosing a DBMS in the LA domain

Generally, a DBMS can run on three types of architectures:

i. *Share-everything* – the DBMS runs on a single machine consisting of a collection of cores sharing a common main memory and disk system. IBM DB2, Microsoft SQL Server, MySQL, Oracle and PostgreSQL are typical DBMSs running on this architecture.
ii. *Share-disks* – the DBMS runs on several machines with independent CPUs and RAM, but stores data on disk cluster that is shared between machines, which are connected via a fast network[15]. IBM DB2 pureScale and Oracle RAC are typical examples of a DBMS running shared disk cluster.
iii. *Share-nothing* – each (virtual) machine running the database is called a *node*. Each node uses its CPUs, RAM and disks independently, and the nodes in a collection of self-contained nodes are connected to one another through networking. CockroachDB (CockroachDB, 2018), FaunaDB (Fauna, Inc., 2019), Google Spanner (Google, Inc., 2019),

VoltDB (VoltDB, Inc., 2019), NuoDB (NuoDB, Inc., 2019) and YugaByte (YugaByte, Inc., 2016-2019) are NewSQL/NoSQL systems running on share-nothing architecture.

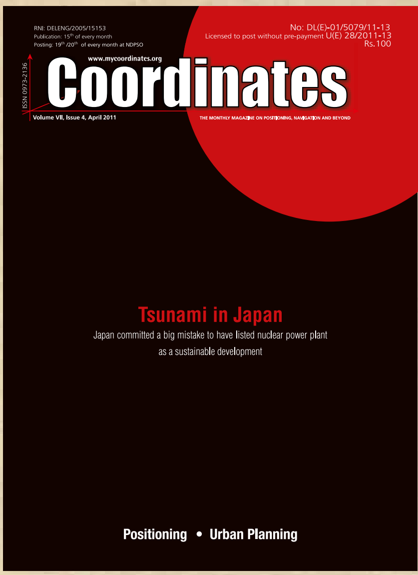
When selecting the right DBMS in building and developing the information systems in the LA domain there are three important criteria to consider (Figure 5):

1. Workload type
   a. Operational database (online transaction processing – OLTP)
   b. Analytical database (online analytical processing – OLAP)
3. SQL and ACID transactions
4. Architecture
   a. Distributed share-nothing

NewSQL DBMS should not be considered as a panacea for building LIS and other relevant data-intensive applications and systems in the LA domain – these systems/applications should be primarily designed and implemented as (i) *resilient*[14]; (ii) *scalable* and (iii) *maintainable*

In Coordinates

10 years before...



mycoordinates.org/vol-7-issue-7-July-2011

Tsunami in Japan

Shunji Murai
Professor Emeritus, University of Tokyo, Japan

RS and GIS are useful to damage assessment to compare between before and after the earthquake and Tsunami. There are two remarkable issues at this juncture that need attention. One was high resolution satellite images which show clearly those damages and accidents of Fukushima Nuclear Power Plants. Air survey was not available because of high atomic radiation in air as well as the destruction of local airports. Satellite images showed the conditions of the power station buildings destroyed by hydrogen gas explosion, which was useful for recovery planning. Another issue was damage assessment to be compared between before and after the Earthquake and Tsunami. As the damaged area was so huge, helicopter is not enough. Satellite images of high resolution and also SAR were very useful to realize the damage scale (see Fig.6). We thank Digital Globe, Google, JAXA, RESTEC and many other organizations to release those satellite images on comparison bases on Internet.

A long way to go

Rajib Shaw
Kyoto University Japan

In the current context, there was a massive earthquake of magnitude 9.0, followed by a gigantic tsunami [in some cases, the height may be more than 15 m, and in some case inland water more than 4 km]. This was followed by the nuclear meltdown, which posed another threat to the already existing grooming situation. Also, there was a cold spell [with snow fall in several parts of the worst affected areas] which also affected the relief and rescue operation. The aftershocks continued for a long time with larger magnitude than the usual one, which shows stronger activity in the fault regions. In the disaster management, we often talk about the worst case scenario, and the disaster preparedness needs to target the worst case scenario. The current multi-disaster situation shows the actual worst case scenario with multiple occurrences of different hazards at the same time. This situation is also one on the rare case of natural disaster causing industrial disasters.

Real time indoor location based service test bed

Li-Ta Hsu, Wen-Ming Tsai and Shau-Shiun Jan
Department of Aeronautics and Astronautics, National Cheng Kung University, Taiwan

The purpose of this paper is to develop low cost and low power consumption Real Time Indoor Positioning System (RTIPS) and then integrate this RTIPS with a self-developed indoor GIS to form a indoor LBS prototype

A geo-spatial approach to urban development

Dr Mahavir
Professor of Planning, School of Planning and Architecture, New Delhi, India

There has been a general tendency of non `geo-spatial' approach to urban planning in India, be it at the National or at the lowest level of hierarchy. No concentrated attempts are in place to plan or recommend an urban settlement pattern in the country, spatially. Urban development, by Constitution, is a state subject. As a result, planning for metropolitan cities and their regions also remains a `local' initiative, though having national ramifications. Absence of a Ministry of Regional (Planning and) Development further contributes to a `non geo-spatial' vision at the National level.

architecture (*horizontal scaling*, aka *scale-out*)
b. Share-everything or share-disk architecture (*vertical scaling*, aka *scale-up*)

Figure 5 shows a simple taxonomic classification of DBMSs based on these three criteria that can be applied in selecting the right DBMS in the LA domain. It also includes typical DBMS products for each class.

Cloud computing

In the recent years, cloud computing has emerged as a computational paradigm for on-demand network access to a shared pool of computing resources (e.g., network, servers, storage, applications, and services) that can be rapidly provisioned with minimal management effort or service provider interaction. Overall, a cloud computing model aims to provide benefits in terms of lesser up-front investment, lower operating costs, higher scalability, elasticity, easy access through the Web, and reduced business risks and maintenance expenses. It offers three key features:

1. Unlimited distributed computing power
2. Unlimited data storage
3. The ability to harness these only as needed – paying only for the consumed resources, rather than buying the resources that might be needed at peak.

Due to such features of cloud computing, many applications and systems have been deployed in the cloud over the last few years. Traditionally, most LA agencies have been purchasing and using on-premise enterprise/legacy IT infrastructure – their IT departments have been managing and maintaining complete IT infrastructure (data center, networking, storage servers, and virtualization), platform (operating systems, databases, security) and all applications (Figure 6). Cloud computing offers three service models (NIST, 2011):

Infrastructure as a Service (IaaS). The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of selected networking components.

Platform as a Service (PaaS). The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

Software as a Service (SaaS). The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface (e.g. web browser), or a program interface. The consumer does not manage or control the underlying cloud infrastructure.

According to (Gartner, Inc., 2019), 75 percent of all databases will be deployed or migrated to a cloud platform by the end of 2022. DBMS cloud services are already $10.4 billion of the $46.1 billion DBMS market in 2018. The overall DBMS market grew at 18.4 percent from 2017 to 2018 (the best growth in over a decade) and cloud DBMS accounted for 68 percent of that growth. This trend reinforces that

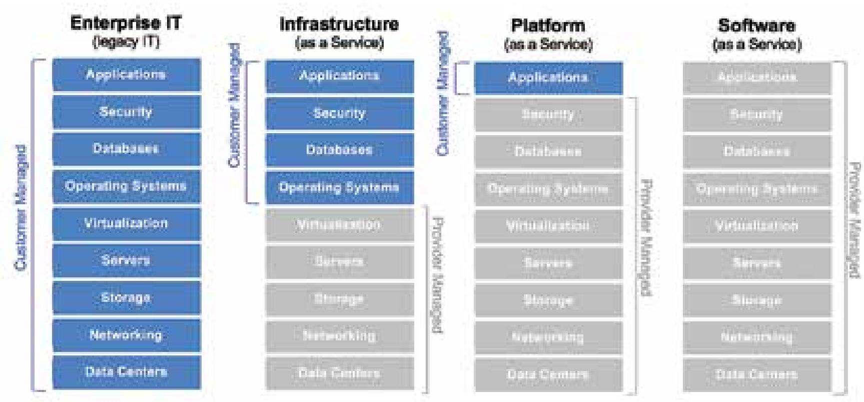


Figure 6. On-premise enterprise/legacy IT and cloud service models

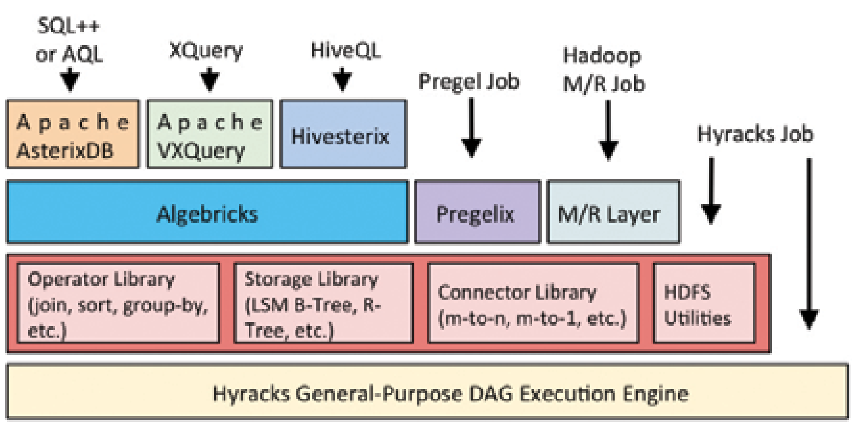


Figure 7. AsterixDB software stack (Carey, 2019)

cloud computing infrastructures and the services that run on them are becoming the new data management platform.

Database as a service (DBaaS) has emerged as a subclass of Software as a Service (SaaS)[16] – it is regulated by the same principles as SaaS and delivers the functionalities of a database management system in the cloud. However, cloud computing imposes new requirements to data management – a cloud DBMSs (either *managed* [17] or *cloud-native* [18]) shall have the following capabilities (Grolinger, Higashino, Tiwari, & Capret, 2013):

- *Scalability and high performance* – today's systems and applications are experiencing continuous growth in terms of the data they need to store, the users they must serve, and the throughput they should provide;
- *Elasticity* – as cloud systems/ applications can be subjected to enormous fluctuations in their access patterns;
- *Ability to run on commodity heterogeneous servers* – as most cloud environments are based on them;
- *Fault tolerance* – given that commodity machines are much more prone to fail than high- end servers;
- *Security and privacy features* – because the data may be stored on third-party premises on resources shared among different tenants;
- *Availability* – as critical systems/ applications have also been moving to the cloud and cannot afford extended periods of downtime.

BDMS- and NewSQL-based LIS prototypes

In this section, we briefly outline two LIS prototypes we are developing at the University of Zagreb, Faculty of Electrical Engineering and Computing. Both protypes implements a reference Land Administration Data Model (ISO, 2012) and a small set of generic CRUD operations and spatial queries.

AsterixDB-based LIS prototype

Apache AsterixDB (Alsubaiee, et al., 2014) is a highly scalable big data management system (BDMS) that aims to support ingesting, storing, indexing, querying and managing semi-structured data. It was co-developed as a research system[19] by the teams of University of California Irvine and University of California Riverside, with the goal to combine the best ideas from the parallel DBMS, Apache Hadoop (Apache Software Foundation, 2019), and the semi-structured data models (e.g., XML/JSON) in order to create a next-generation BDMS. Apache AsterixDB core features include (Apache Software foundation, 2016):

- A semi-structured NoSQL-style data model based on JSON extended with ODBMS concepts.
- Two declarative query languages for querying semi-structured data.
- Apache Hyracks runtime query execution engine, for partitioned-parallel execution of query plans.
- Support for querying external data (e.g., in HDFS) as well as

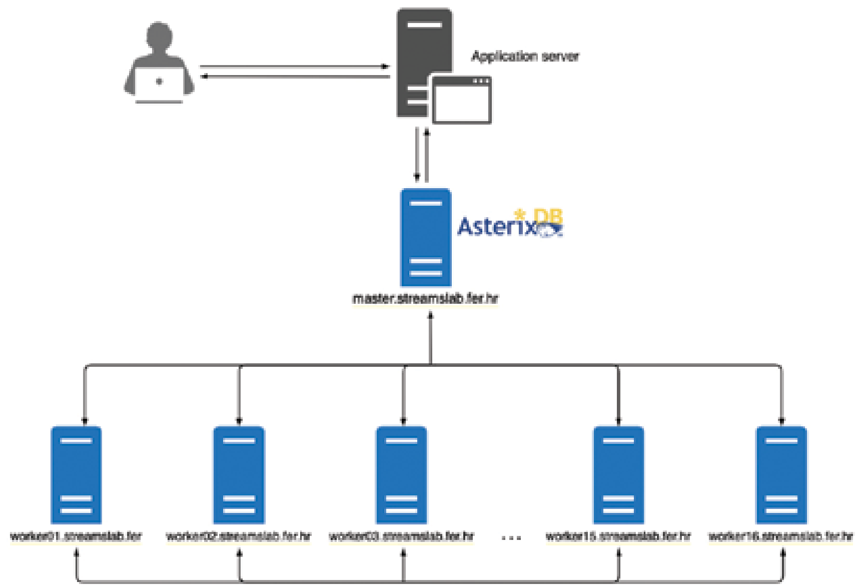


Figure 8. Deployment of AsterixDB-based LIS prototype

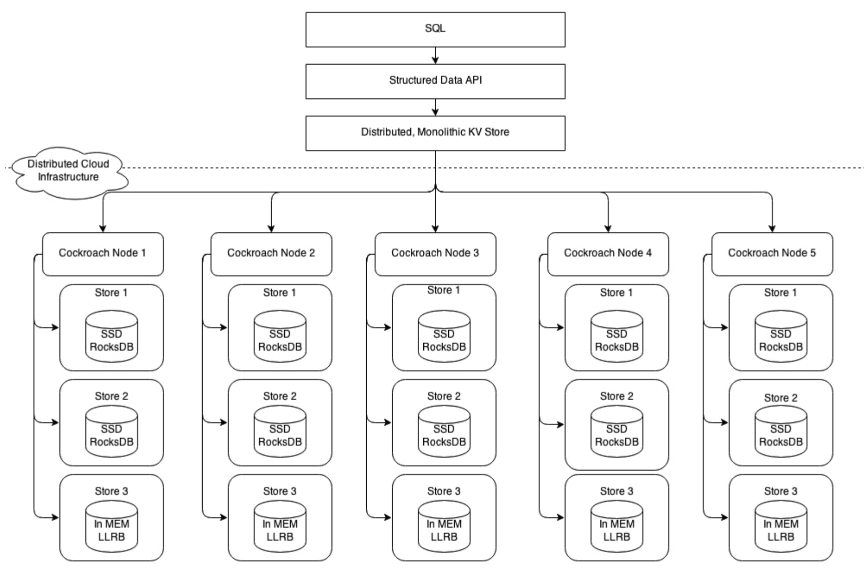


Figure 9. CockrachDB architecture (CockroachDB, 2018)

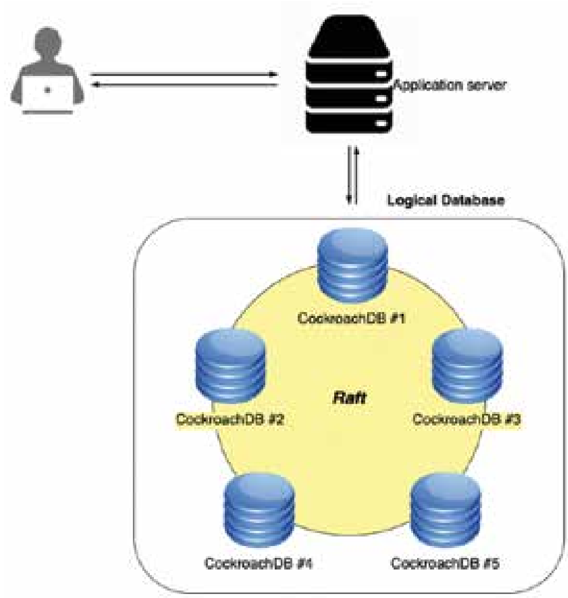


Figure 10. Multi-active availability with 5 CockroachDB nodes

The majority of the existing LIS are predominantly online transaction processing (OLTP) systems, built on (object-)relational database management systems. These *traditional* database management systems are not designed to take advantage of distributed and cloud computing. They only support vertical *(scale-up)* rather than horizontal *(scale-out)* scalability, which is more common in distributed systems and applications.

data stored within AsterixDB.

- A rich set of primitive data types, as well as OGC support for spatial data[20].
- Indexing options that include B+ trees, R trees, and inverted keyword index types.
- Basic transactional (concurrency and recovery) capabilities akin to those of a NoSQL.

The availability of two declarative query languages, namely AQL and SQL++ (Ong, Papakonstantinou, & Vernoux, 2015), strongly distinguish Apache AsterixDB from the most NoSQL DBMS, therefore classifying it as *Not only SQL* BDMS.

Figure 8 shows the deployment of our AsterixDB-based LIS prototype on a computer cluster consisting of 16 workers (each with 8 CPU cores, 16 GB RAM, 1TB HDD and Linux OS), which is available in our Data Streams Laboratory[21].

CockroachDB-based LIS prototype

CockroachDB (Cockroach Labs, 2019) is a cloud-native, distributed DBMS (i.e., CP system according to the CAP theorem), primarily designed for (i) *horizontal scalability*; (ii) *strong consistency* and (iii) *disaster resilience* (*survivability*). Disaster resilience aims to tolerate disk, machine, rack, and even data center failures with minimal latency disruption and without manual intervention. It is an open source derivate of Google Spanner[22] (Google, Inc., 2019), built on top of RocksDB (Facebook, Inc., 2019) distributed key/value storage engine, and can be deployed on and across any public or private cloud[23] as fully managed version.

CockroachDB implements a layered architecture (Figure 9). The highest level of abstraction is the SQL layer, which provides standard concepts such as schemas, tables, columns, and indexes. The SQL layer in turn depends on the distributed key-value store, which handles the details of range addressing to provide the abstraction of a single, monolithic key-value store. The distributed key- value store communicates with any number of physical CockroachDB nodes, with each node containing one or more stores, one per physical device (CockroachDB, 2018).

The CockroachDB-based LIS prototype is being developed using Go programming language (Google, Inc., 2019) and GORM object-relational mapping library (Jinzhu, 2019). Built on CockroachDB, it is well suited for the cloud computing era and cloud deployment, including Docker containerization (Docker, Inc., 2019) and Kubernetes orchestration (Linux Foundation, 2019). Figure 10 shows the deployment of our LIS prototype on 5 CockroachDB nodes, each with 8 CPU cores, 16 GB RAM, 1TB HDD and Linux OS.

Through *multi-active availability* replication (Figure 10), where each node in the cluster performs *read* and *write* operations without generating conflicts and/or anomalies, our LIS prototype ensures *strong consistency, high availability* and *outstanding resilience*. CockroachDB can handle up to F node failures, where the replication factor N = 2F + 1; therefore, our prototype deployment environment can handle up to 2 node failures. Raft consensus algorithm (Ongaro & Ousterhout, 2014) ensures that a majority of the data's replicas are identical, and a minority of nodes can be down without stopping the database from making progress.

Conclusions

The majority of the existing LIS are predominantly online transaction processing (OLTP) systems, built on (object-)relational database management systems. These *traditional* database management systems are not designed to take advantage of distributed and cloud computing. They only support vertical (*scale-up*) rather than horizontal (*scale-out*) scalability, which is more common in distributed systems and applications.

Blockchain is one of the hottest topics in contemporary distributed transaction processing. However, despite all the hype around the blockchain technology, many of the tradeoffs, issues and challenges that blockchain systems espouse are yet to be resolved. They perform poorly at data- intensive OLTP tasks and the performance gap between them and DBMSs is still too big for blockchains to be disruptive to state-of-the-art distributed DBMSs. Improving blockchain performances by introducing distributed DBMSs designs into blockchain, including a high-level SQL interface, seems like a promising approach, but there is still a long way to go.

Distributed computing systems and shared-nothing architecture became very popular during the last decade, including new data processing platforms/frameworks with scalability and fault tolerance capabilities. These new systems/frameworks use large amounts of *commodity hardware* to store, manage and analyze data in a highly distributed, scalable and cost-effective way.

The key feature of NoSQL systems is that they sacrifice ACID transactional guarantees and the (object-)relational model of traditional DBMSs in favor of *eventual consistency* and other data models (e.g., key/value, graphs, documents). This is because it was believed that these aspects of existing DBMSs inhibit their ability to scale horizontally and achieve the *high availability*. However, many mission-critical enterprises applications, including LIS, are not able to use NoSQL systems simply because they cannot give up strict transactional and consistency requirements.

For OLTP systems with the potential for massive scale, NewSQL DBMSs provide a compelling solution with potential throughput that reaches millions of transactions per second. Although primarily designed to support the ACID-transactional workloads in enterprise applications and systems, NewSQL DBMSs have had a relatively slow rate of adoption in the LA domain. Data- intensive OLTP applications and systems, including LIS, should be primarily designed and implemented as *resilient*, *scalable* and *maintainable* systems that guarantee *consistency*, built on the *"invest in data/system resilience, not disaster recovery"* paradigm. NewSQL DBMSs are designed and developed exactly for these purposes, and LIS system/software architects should seriously consider NewSQL DBMS, distributed and cloud computing in designing, building and deploying the next generation of LIS. We also advocate that the next generation of LIS should remain data-intensive OLTP systems built on SQL/ACID standards, NewSQL DBMS and gain effectiveness from distributed and cloud computing as new LIS data management platforms.

Acknowledgment

The author would like to thank his postgraduate students Natko Bišćan and Mario Vuzem for their engagement and great work in implementing two presented prototypes.

Endnotes

[1] Atomicity, Consistency, Isolation, Durability – a set of properties of database transactions that guarantee validity.

[2] A distributed system is a collection of autonomous computing elements (nodes) that appears to its users as a single coherent system (van Steen & Tanenbaum, 2017).

[3] On-line transaction processing (OLTP) benchmark.

[4] An open-source permissioned blockchain system (https://github.com/hyperledger/fabric)

[5] Ethereum, Parity and Hyperledger

[6] There has been a lot of academic debate on CAP confusion and misleading interpretation – interested readers can refer to (Brewer, CAP Twelve Years Later: How the "Rules" Have Changed, 2012), (Abadi, Consistency Tradeoffs in Modern Distributed Database System Design: CAP is Only Part of the Story, 2012), (Kleppmann, A Critique of the CAP theorem, 2015) and (Mahajan, Alvisi, & Dahlin, 2011) for more details.

[7] A *network partition* refers to a situation where one part of the network is cut off from the rest due to a network fault.

[8] NoSQL community claims that NoSQL should be interpreted as *"Not only SQL"*, because some systems support high-level SQL-like languages.

[9] No system can guarantee 100% availability.

[10] Sometimes called *horizontal scaling* or *scaling out*.

[11] Multi-document transactions

[12] Document-only

[13] Row-only; distributed transactions and ACID semantics across all data in the database requires an additional library.

[14] aka *fault-tolerant, reliable*.

[15] SAN (Storage Area Network)

[16] Oracle Cloud Platform (OCP) offers DBaaS as a subclass of PaaS.

[17] No significant modification to the DBMS to be "*aware*" that it is running in a cloud environment.

[18] DBMS is designed explicitly to run in a cloud environment.

[19] Couchbase Analytics uses Apache AsterixDB as the storage and parallel query engine.

[20] https://github.com/apache/asterixdb/commit/ 8cc882538af1e74cc1f92eb42d24d76370384279

[21] https://streamslab.fer.hr

[22] But without the hardware infrastructure upon which Spanner relies at Google.

[23] Cockroach Cloud is available on Google Cloud and AWS (Amazon Web Services).

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The high cost of low-hanging fruit

Low-hanging fruit refers to the obvious and easy things you do to achieve success or make progress toward a goal. It's the easy stuff. It's the things that always work

Brent Jones, PE, PLS
Esri, USA

Why is this a problem?

We all want the easy way to get the job done, but it's a problem because disruption sniffs out complacency. Low-hanging fruit is the target of disruption *because* it's easy. Advancing technology solves easy problems efficiently, so anyone can do it.

Relying on low-hanging fruit is well described in the book *Who Moved My Cheese?,* the often recommended (and ridiculed) book on change management. In it, mice who constantly seek security are upended by the possibility that they may lose it.

There is no security in the easy stuff. Relying on past patterns, regulations, and holding on to the status quo because "That's the way it's always been," and "We don't do that" are all ingredients in the recipe for obsolescence.

As enior vice president at a company I worked at many years ago said, "Don't worry about the phone ringing. It has always rung." That was true… until it wasn't. That company is now a shell of its former existence.

Complacency invites disruption and is the cousin of failure. I'm not saying you shouldn't pick the low-hanging fruit. I'm saying that if that's all you do, you're doomed.

Artificial intelligence (AI) and machine learning are real, and they're coming fast. What were once time-consuming human in- telligence activities are becoming automated and combined with rapidly growing cloud capabilities. This will replace core work flows for many professionals such as lawyers, appraisers, assessors, ac- countants, and surveyors. Our ability to use AI with GIS and ad- vanced spatial analysis capabilities are rapidly moving the dial. There's hardly an areath at won't be touched as one business over- takes the core business of another.

This equals disruption. Are you ripe for disruption? Probably.

We all are. Everything is changing and will continue to do so.Our cheese is getting moved, and our low-hanging fruit is being eyed by others. What do we do to prevent the disruption of our work? How do we prevent what Uber did to taxis from happening tous?

It's surprisingly simple. Transformation is disruption that you do toyourself.Disrupt your organization from the inside. Take the lead. Build resilience to external disruption. Do this by staying current with your technology.Technology is moving ahead farm orerapidly than it did just a few years ago, and the acceleration will increase.

Thomas Edison once said, "I start where the last man left off." Use this to your advantage. Don't reinvent the wheel. Use what's been done to leapfrog your organization ahead of where it is today. This requires a bit of work, but what worked in the past will prob- ably not work long into the future.

Jack Dangermond, president and founder of Esri, has said many times, "Act like a startup." This means work lean, innovate, make mistakes, try new things, get out of your comfort zone, and do it quickly. These strategies are all important to defend against exter- nal disruption.

There is no better time than today to get started with your trans- formation. It will be more difficult next month, and more difficultthe following month. I doubt it will stop.

Get started.

Network with peers, vendors, and suppliers. Attend a confer- ence or webinar. Join an association committee. Look at which communities your peers are connected to.

I cut a quote by former IBM president Tom Watson, Jr., out of the newspaper and hung it near my desk for many years. It's perhaps more pertinent now than it was in the 1950s when he said it.

"Solve it. Solve it quickly, solve it right or wrong. If you solve it wrong, it will come back and slap you in the face, and then you can solve it right. Lying dead in the water and doing nothing is a com- fortable alternative because it is without risk, but it is an absolutely fatal way to manage a business." Your low-hanging fruit is being moved. Move with it.

The article first published at https://www.esri.com/about/newsroom/arcuser/the-high-cost-of-low-hanging-fruit/

Update on major activities undertaken by the Department of Space in the year 2020-21

The Department of Space, Government of India has the primary responsibility of promoting the development of space science, technology and applications towards achieving self-reliance and facilitating in all round development of the nation. The report narrates all the major activities of the department including navigation, earth observation and Gaganyaan

Department Of Space (DOS), Government of India has recently released the annual report 2020-2021. The report updates the major activities undertaken by the department in the year 2020-21. DOS has the primary responsibility of promoting the development of space science, technology and applications towards achieving self-reliance and facilitating in all round development of the nation. The report narrates all the major activities of the department including navigation, earth observation and Gaganyaan. The complete report can be accessed at https://www.isro.gov.in/2020-2021-english.

Satellite Navigation (SATNAV) is one of the important programmes of the Department. There are two main components of this program.

- GAGAN
- Navigation with Indian Constellation (NavIC).

GPS Aided Geo Augmented Navigation (GAGAN)

The GPS Aided Geo Augmented Navigation (GAGAN) system is developed by Indian Space Research Organization (ISRO), together with Airports Authority of India (AAI) to deploy and certify an operational SBAS-Satellite Based Augmentation System for the Indian Flight Information Region (FIR), with expansion capability to neighboring FIRs. GAGAN provides a civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) as established by the GNSS Panel.

The GAGAN is presently operational with three signals in space (PRN 127, PRN 128, PRN 132) from three GEO satellites viz GSAT-8, GSAT-10 and GSAT-15 respectively. According to the annual report, the renewal activities for the allocation of PRN 127 and PRN 128 for a

ISRO has become part of an initiative by the National Disaster Management Agency (NDMA) to evolve a Common Alert Protocol (CAP) for major natural disasters like landslides, earthquakes, floods, heavy rains, avalanches, etc. NavIC Messaging System has been recognized as an effective means of disseminating the alert messages and is taken up for phase-1 implementation period of 10 years have been completed. GAGAN certification for Navigation Performance level of Approach with Vertical Guidance (APV-1) over India & Required Navigation Performance (RNP 0.1) within Indian Flight Information Regions has been extended for further 24 months with effect from Jul 19, 2020.

Deployment Readiness Test (DRT) of new software was held from Sep 28 to Oct 11, 2020 at Bengaluru and ISRO and DGCA members reviewed the procedures and test results. Technical Review Team (TRT) meeting was held on Nov 05, 2020 to review, provide directions and guidance for GAGAN program.

Navigation with Indian Constellation (NavIC)

NavIC is an independent regional navigation satellite system developed and maintained by India. It is designed to provide accurate Position Velocity and Timing (PVT) information service to users in India as well as the region extending up to 1500 km from its boundary, which is its primary service area (5°S to 50°N and 55°E to 110°E). NavIC is providing two types of services, namely, Standard Positioning Service (SPS) and Restricted Service (RS) and is expected to provide a position accuracy of better than 20m (2σ) over the primary service area and timing accuracy better than 40 ns (2σ). The IRNSS system consists of Ground Segment, Space Segment and User Segment.

(a) Space Segment

The NavIC space segment constellation is configured with seven satellites with three in Geo Synchronous Orbit (GSO) and four in Inclined Geo Synchronous Orbit (IGSO). The constellation has been operational since June 2016. IRNSS-1A and IRNSS-1G are currently being used for short messaging services. The replacement satellite IRNSS 1I (for IRNSS 1A) was launched on April 2018 and is currently operational. NVS-01 is planned as replacement satellite for IRNSS-1G. NVS-01 is under development and it is planned to be launched in 2021-22.

The updated version of IRNSS SPS Interface Control Document (ICD) (version 1.1) has been hosted in ISRO website with information to utilize the services of IRNSS-1I. The Indian Regional Navigation Satellite System (IRNSS) has been accepted as a component of the World-Wide Radio Navigation System (WWRNS) for operation in the Indian Ocean Region by the International Maritime Organization (IMO).

(b) Ground Segment

- The ISRO Navigation Centers (INC) are operational at Byalalu, Bengaluru and Lucknow. INC1 (Byalalu) and INC2 (Lucknow) together provide seamless operations with redundancy.
- IRNSS Network Timing facility (IRNWT-I) is operational at Byalalu, Bengaluru. The IRNWT-II has been established at Lucknow and is operational since February 2018. Both the Timescales at IRNWT-I and II operate with a difference of 20ns (2σ) accuracy with respect to UTC. Two Way Satellite Time and Frequency Transfer (TWSTFT) and Global Navigation Satellite System (GNSS) all-in-view methods are used for time synchronization between INC-1 and INC-2 and with National Physical Laboratory India (NPL-I).
- Sixteen IRNSS Range & Integrity Monitoring Stations (IRIMS) are operational with fifteen of these stations located within the country and one at Mauritius. Additional future IRIM stations establishment at Japan and Russia in progress.
- The IRNSS Data Communication Network (IRDCN) with Terrestrial and Very Small Aperture Terminal (VSAT) links is operational with redundancy among all the ground elements.
- The IRNSS Spacecraft Control Facility (IRSCF), monitors and controls the IRNSS satellites and is operational at Master Control Facility (MCF) Hassan and Bhopal. The IRSCF uplinks the navigation data to the satellites in addition to regular TT&C operations. IRSCF stations at MCF- Hassan and Bhopal work as redundant to each other for IRNSS TTC operations.
- Four IRNSS CDMA Ranging (IRCDR) stations are operational at Hassan, Bhopal, Shillong and Jodhpur. These stations are used for two-way ranging of IRNSS satellites. Two additional IRCDR stations are planned at Trivandrum and Port Blair.

(c) User Segment

ISRO is involved in the development and technology transfer of various types of user receivers. The following types of receiver and receiver technology are being developed.

- FPGA based SPS receiver design and development
- 36 Channel configurable SPS Base Band ASIC based receiver
- G3I NavIC BB Application Specific Integrated Circuit (ASIC) Receiver with Lower Node technology
- Payload Coherency Test Receiver
- Design and development of receivers for new L1 civilian signal. \

Major developments

• ***Recognition by International Maritime Organisation*** - As a part of the objective to enable applications of NavIC in maritime field, ISRO submitted documents related to the performance, test results and applications of NavIC to International Maritime Organization (IMO). Through Director General of Shipping (DGS), ISRO attended the meetings of Maritime Safety Committee (MSC) and Sub-Committee on Navigation, Communication and Search and Rescue (NCSR) of IMO. In the 102nd session of the Maritime Safety Committee (MSC-102) held in November 2020, IMO recognized NavIC as a component of the WWRNS. It stated that NavIC meets the operational requirements to assist in the navigation of ships in ocean waters.

• ***Incorporation in Radio Technical Commission for Maritime Services (RTCM) standard*** - RTCM Standard

10403.3 defines the standards for Differential Global Navigation Satellite Systems (DGNSS). NavIC L5 successfully cleared all the tests for incorporation into RTCM standard. The Special Committee (RTCM SC-104) during its meeting in May 2020 approved NavIC L5 signal to be included in the RTCM standard. The latest release of RTCM 10403.3 Standards Amendment-1 includes NavIC L5. This will enable NavIC application in the differential GNSS catering to maritime, surveying, construction, asset monitoring, deformation monitoring, geodesy, etc.

Incorporation in 3GPP standard - ISRO in co-operation with members of Telecom Standards Development Society of India (TSDSI) has been working towards inclusion of NavIC in 3GPP standards for assisted GNSS in the 4G. In 2019, 3GPP had adopted Work Item for inclusion of NavIC into the 4G standard. As part of the Work item activity, NavIC Receiver Compliance Performance Standards were submitted to 3GPP. During its 110th meeting of RAN-4 held in June 2020, 3GPP approved inclusion of NavIC in Release 16.This step will enable advanced positioning features like indoor positioning, better battery efficiency, fast position fix, etc. with NavIC satellite system.

• **NavIC in Mobiles:** To enable the use of NavIC in mobile phones, efforts are being channelized with the following stakeholders.

a. Chip Manufacturers: Major mobile chipset manufacturers (Qualcomm, Mediatek) have released mobile processors which are NavIC enabled. These releases have started since January 2020.
   - Qualcomm – Snapdragon 460, 662,690,720G, 765,865, 888
   - Mediatek – Dimensity 800, 1000

• **NavIC in low power GNSS chips:** ISRO has provided technical support to chip manufacturers like Allystar, Trimble, Quectel, Skytraq, U-Traq, Accord, Broadcom, etc. to enable inclusion of NavIC in their GNSS chips. Due to this, all these manufacturers have support for NavIC L5 signal in their latest chips. This has facilitated usage of NavIC L5 in many civilian applications including vehicle location tracking. However, newer applications like wearable devices, personal trackers, IoT devices, etc. which require small form factor and very low power are generally catered to by single frequency (L1) modules. The wearable devices market in India is anticipated to expand at the rate of ~26% per annum (source: market reports). In order to proliferate NavIC in this sector, all the subsequent satellites will feature L1-band signal in addition to the legacy L5 and S bands. ISRO conducted an interface meeting with all the major chip manufacturers in March 2020 and introduced them to the new L1 signal. ISRO is sharing all the relevant technical details with the chip manufacturers to facilitate inclusion of NavIC L1 into low power GNSS chips at the earliest.

• **NavIC Messaging Service:**

a. NavIC Messaging Receiver:

- Indian National Centre for Ocean Information System (INCOIS) is effectively using the NavIC messaging service to broadcast alerts messages such as cyclone, high wave etc. and provide information on Potential Fishing Zone (PFZ) for the fishermen venturing into deep sea. ISRO has become part of an initiative by the National Disaster Management Agency (NDMA) to evolve a Common Alert Protocol (CAP) for major natural disasters like landslides, earthquakes, floods, heavy rains, avalanches, etc. NavIC Messaging System has been recognized as an effective means of disseminating the alert messages and is taken up for phase-1 implementation.

b. Second Generation Distress Alert Transmitter (SG-DAT):

ISRO developed Second Generation Distress Alert Transmitter (SG-DAT) by integrating the features of NavIC Messaging Receiver (NMR) and Distress Alert Transmitter (DAT). In this system, fishermen can send a distress alert through the regular DAT link to the rescue centre and the acknowledgement for the reception of distress signal and impending rescue attempt will be sent through the NavIC messaging service. The hub has been established at ISTRAC along with the existing COSPARSARSAT ground system. SG-DAT terminal prototype development is completed and technology has been transferred to six industries through NSIL for commercial deployment.

- **NavIC based Timing applications** - ISRO and NPL are assisting Department of Consumer Affairs to establish one primary timescale (stratum 0) at Bengaluru and five secondary timescales (stratum 1) at Ahmedabad, Bengaluru, Bhubaneswar, Faridabad and Guwahati. These timescales will be integrated and operate with in-house ISRO's timescale software suite. The system architecture has been finalised and cleared for procurement. These timescales will provide accurate IST dissemination across India and would ensure national security and enhances cyber security resilience.

- **NavIC Performance Evaluation** - NavIC performance is evaluated on quarterly basis and the performance evaluation reports are uploaded to the ISRO website on regular basis. Five reference receiver locations are identified in North, South, East, West and Central regions of the country to carry out the detailed performance evaluation. NavIC dual frequency SPS signals are used to check the performance from the user perspective. The achieved position accuracy is better than 10m (2σ). NavIC - GPS (Global Positioning System) - SBAS (Satellite Based Augmentation System) user receivers are being procured by Satellite Navigation Programme (SNP) for performing the NavIC SPS signal performance evaluation in NavIC

Gaganyaan is the first project taken up by HSFC for demonstrating human spaceflight capabilities. It is the maiden manned mission of ISRO which involves development of a host of new technologies and activities that need to be taken up concurrently across all ISRO Centres within the stipulated schedule

service area. Presently the acceptance testing of receiver is in progress. These receivers will be deployed across India for remote navigation data collection and performance evaluation.

- **Incorporation of NavIC in Interoperable Space Service Volume (SSV)** - The Space Service Volume (SSV) provides definition for interoperable GNSS SSV for space users and space receiver manufactures. ISRO is a part of the task team constituted under International Committee on GNSS (ICG) comprising of all GNSS service providers. Analysis and simulation(s) have been carried out for evaluating the availability / signal strength of GNSS satellites for space users. Based on the simulation study, the SSV booklet version-1 has been released by United Nation Office for Outer Space Affair (UNOOSA).

Future missions

The current NavIC satellite constellation comprises of six operational navigation satellites and two satellites for messaging services. It is planned to realize five navigation satellites viz., NVS-01/02/03/04/05 as replacement to the satellites in the current constellation. NVS-01 satellite is in developmental stage and it will be placed at IRNSS-1G. These satellites shall be located at the existing orbital slots and ensure continuity of NavIC services.

NVS-01/02/03/04/05 will be configured with navigation payloads in L5 & S bands and ranging payload in C-band similar to existing IRNSS satellites. Additionally, it is proposed to incorporate a new interoperable civil signal in L1 frequency in the navigation payload. These replacement satellites, with a targeted mission life of minimum 12 years.

Earth Observation

EOS-01 was successfully realized and launched onboard PSLV-C49 on Nov 07, 2020. The primary objective of the mission is to provide X band SAR imaging services with improved frequency of observation over area of interest. The satellite has the capability to operate in day, night and all-weather conditions and provides imaging data for various applications related to land, water & environment which is required for agriculture, forestry, water resource, flood inundation estimation and disaster management. This is the third satellite in the constellation of three satellites to meet the user requirement. All three satellites in the constellation viz RISAT-2B, RISAT-2BR1 and EOS-01 are performing to specification and providing satisfactory services to the users.

Gaganyaan – Human Space Flight

Gaganyaan is the first project taken up by HSFC for demonstrating human spaceflight capabilities. It is the maiden manned mission of ISRO which involves development of a host of new technologies and activities that need to be taken up concurrently across all ISRO Centres within the stipulated schedule. The objective of Gaganyaan is to carry a crew of three to Low Earth Orbit (LEO), perform a set of predefined activities in space, and return them safely to a predefined destination on earth.

New systems are required to undertake human spaceflight namely Human rated launch vehicle, Crew Module (CM) system, Service Module (SM) system, Crew Escape System (CES) and Environmental Control and Life Support System (ECLSS). The crew selection and training, development of human centric products, human rating certification system, dealing with man- machine interfaces are other domains of manned space flight that is addressing concurrently.

The human rating of GSLV MKIII has already been initiated at VSSC. The launch complex system at SDSC-SHAR and ground infrastructure are being augmented towards accommodating the crew activities. Communication network including ground based and space-based systems is planned to provide near 100 % coverage during various phases of mission viz., ascent, on-orbit, re-entry and descent. Selection of crew for the first mission has been completed and crew training activities are in progress at Russia in association with Indian Air Force. Plan of action is in place towards realization of human centric products with the assistance of Defence Research and Development Organisation. An Inter-agency committee for recovery of crew with Indian navy in lead role has been constituted and the committee has initiated the crew recovery related activities.

Many tests are planned to validate launch vehicle technologies. These tests are planned before the launch of first unmanned flight. Such as:

- Test Vehicle Mission for Escape System Qualification
- HS200 static test
- Vikas Engine Hot Test
- CE20 Hot Test

Source: Annual Report 2020-2021, Government of India, Department of Space www.isro.gov.in/2020-2021-english

The U.S. space-based PNT policy

The USA has issued the Memorandum on Space Policy Directive 7 on January 15, 2021. This Space Policy Directive establishes implementation actions and guidance for United States space-based Positioning, Navigation, and Timing (PNT) programs and activities for United States national and homeland security, civil, commercial, and scientific purposes

This policy complements the guidance set forth in Executive Order 13905 of February 12, 2020 (Strengthening National Resilience through Responsible Use of Positioning, Navigation, and Timing Services), and the intersector guidance for Global Navigation Satellite Systems (GNSS) included in the December 9, 2020, National Space Policy. This policy supersedes National Security Presidential Directive-39 (NSPD-39) of December 15, 2004 (United States Space-Based Positioning, Navigation, and Timing Policy).

Section 1. Scope

This policy directive provides guidance for:

(a) sustainment and modernization of the Global Positioning System (GPS) and federally developed, owned, and operated systems used to augment or otherwise improve GPS;

(b) implementation and operation of capabilities to protect United States and allied access to and use of GPS for national, homeland, and economic security, and to deny adversaries hostile applications use of United States space-based PNT services; and

(c) United States participation in international cooperative initiatives regarding foreign space-based PNT services and foreign use of GPS and its augmentations.

Sec. 2. Definitions

In this section, various terms have been defined for the purpose of this document. The same can be seen in the complete document at https://trumpwhitehouse.archives.gov/presidentialactions/memorandum-spacepolicy-directive-7/

Sec. 3. Background

The multi-use services provided by GPS are integral to United States national security, economic growth, transportation safety, and homeland security. These services are essential but largely invisible elements of worldwide economic infrastructures.

(a) Responsible use of Space–Based PNT.

(i) GPS is a key component of multiple sectors of United States critical infrastructure, as identified in Presidential Policy Directive-21 (PPD-21) of February 12, 2013 (Critical Infrastructure Security and Resilience) and stated in EO 13905. Cascading effects from extended PNT service disruption or denial can adversely affect all sectors. Autonomous vehicles on land, sea, and air have begun to rely on GPS for navigation, positional awareness, and other vehicle capabilities. Additionally, many information systems rely on the GPS timing signal to enable both fixed and mobile communications. An extended outage of GPS, or extended period of spoofed or manipulated GPS signals, could cause severe economic losses and put lives at risk.

(ii) GPS remains critical to United States national security. Its applications are integrated into virtually every facet of United States military operations. United States and allied military forces will continue to equip and train for the responsible use of GPS and alternative PNT services to support mission operations.

(iii) The widespread and growing dependence on GPS by military, civil, and commercial applications, systems, and infrastructure make the performance of many of these systems inherently vulnerable if disruption or manipulation of GPS signals were to occur. GPS users must plan for potential signal loss and take reasonable steps to verify or authenticate the integrity of the received GPS data and ranging signal, especially in applications where even small degradations can result in loss of life. In addition, whether designed for military capabilities or not, signals from PNT services and their augmentations provide inherent capabilities that may be used by adversaries, including enemy military forces and terrorist groups.

(b) Space Applications. Applications for GPS now extend beyond Earth. The Terrestrial Service Volume of GPS, defined as the volume from the ground to an altitude of 3,000 kilometers, has become an integral component for space launch operations. Use of GPS is expanding into the Space Service Volume (SSV), which extends from 3,000 km to geosynchronous Earth orbit (GEO), despite reduced line-of-sight visibility and lower received signal power. Satellites rely on GPS for navigation, attitude control, space situational awareness, and new space science applications such as radio occultation. Consistent with Space Policy Directive-1 (SPD-1) of December 11, 2017 (Reinvigorating American's Human Space Exploration Program) and Space Policy Directive-3 (SPD-3) of June 18, 2018 (National Space Traffic Management Policy) PNT services will also play an important role in space traffic management and future applications in the Cislunar Service Volume, which extends from GEO out to and including the Moon's orbit. For requirements necessary to support these emerging applications, agencies should coordinate through standard GPS requirements processes.

(c) Foreign Space-Based PNT. Emerging foreign space-based PNT services could enhance or undermine the future utility of GPS. The United States will continue to encourage the development of foreign space-based PNT services based on GPS and their responsible use in non-military applications with allied and likeminded nations. Use of multiple, varied PNT services can result in better performance in terms of user accuracy, availability, and resilience. However, the United States Government does not assure the reliability or authenticity of foreign PNT services. Although foreign space-based PNT services may be used to complement civil GPS service, receiver manufacturers should continue to improve security, integrity, and resilience in the face of growing cyber threats. Thus, incorporation of foreign PNT in multi-constellation devices should be designed in a manner that precludes potential degradation of essential user capabilities resulting from possible foreign global navigation satellite system (GNSS) origins. The United States will maintain awareness of the risks and potential benefits associated with the use of foreign space-based PNT services and continue to promote and support the responsible use of GPS as the pre-eminent space-based PNT service.

(d) United States Policy and Management Framework.

(i) The United States continues to improve and maintain GPS and its augmentations to meet growing national, homeland, and economic security requirements as well as other civil requirements, and to enable diverse commercial and scientific applications. In parallel, the United States continues to improve capabilities to deny adversary access to space-based PNT services, particularly including services that are openly available and can be readily used by adversaries or terrorists, to threaten the security of the United States. The United States is addressing risks associated with dependence on space-based PNT and fostering responsible use approaches to PNT service acquisition, integration, and deployment across critical infrastructures. The United States is also encouraging the development of alternative approaches to PNT services and security that can incorporate new technologies and services as they are developed, such as quantum sensing, relative navigation and private or publicly owned and operated alternative PNT services.

(ii) The diverse requirements for and multiple applications of space-based PNT services require stable yet adaptable policies and management mechanisms. Therefore, the United States Government will continue to support a policy and management framework governing GPS and its augmentations that meets increasing and varied domestic and global requirements.

Sec. 4. Policy Goals and Guidance

The goal of this policy is to maintain United States leadership in the service provision, and responsible use of global navigation satellite systems, including GPS and foreign systems. To this end, the United States Government shall:

(a) Provide continuous worldwide access to United States space-based GPS services and government-provided augmentations, free of direct user fees, and provide open, free access to information necessary to develop and build equipment to use these services;

(b) Operate and maintain the Global Positioning System in accordance with United States law to satisfy civil, homeland security, and national security needs, consistent with published performance standards and interface specifications;

(c) Improve NAVWAR capabilities to deny hostile use of United States Government space-based PNT services, without unduly disrupting civil and commercial access to civil PNT services outside an area of military or homeland security operations;

(d) Improve the performance of United States space-based PNT services, including developing more robust signals that are more resistant to disruptions and manipulations consistent with United States and allied national security, homeland security, and civil purposes;

(e) Improve the cybersecurity of GPS, its augmentations, and United States Government owned GPS-enabled devices, and foster private sector adoption of cyber-secure GPS enabled systems through system upgrades and incorporation of cybersecurity principles for space systems, interface specifications, and other guidance that prescribes cybersecurity for user equipment;

(f) Protect the spectrum environment that is currently used by GPS and its augmentations, and work with United States industry to investigate additional areas of the radio spectrum which could increase GPS and PNT resilience;

(g) Invest in domestic capabilities and support international activities to detect, mitigate, and increase resilience to harmful disruption or manipulation of GPS, and identify and implement, as appropriate, alternative sources of PNT for critical infrastructure, key resources, and mission-essential functions;

(h) Maintain GPS and its augmentations for use by United States critical infrastructure to enhance safety of life functions and operational efficiency, consistent with PPD-21;

(i) Engage with international GNSS providers to
ensure compatibility, encourage interoperability with likeminded nations, promote transparency in civil service provision, and enable market access for United States industry. Encourage foreign development of PNT services and systems based on GPS and the inclusion

of GPS as an essential element in systems that integrate multiple PNT services. At a minimum, seek to ensure that all foreign systems are compatible with GPS and its augmentations, that they do not interfere with GPS military and civil signals, and that mutual security concerns are addressed to prevent hostile use of United States space-based PNT services;

(j) Promote the responsible use of United States space-based PNT services and capabilities for applications at the Federal, State, and local level, consistent with Executive Order 13905; and

(k) Promote United States technological leadership in the provision of space-based PNT services and in the development of secure and resilient end user equipment.

Sec. 5. Management of Space-Based PNT Services

(a) The National Space-Based Positioning, Navigation, and Timing Executive Committee (Executive Committee) is the interagency body responsible for guiding and preserving whole-of-government interests in the provision of space-based PNT services, augmentations, and space-based alternatives. The Deputy Secretaries of the Department of Defense and the Department of Transportation, or their designated representatives, shall co-chair the Executive Committee.

(b) In addition to the Co-Chairs, the members of the Executive Committee shall be at the deputy secretary level or equivalent from the Department of State, the Department of the Treasury, the Department of Justice, the Department of the Interior, the Department of Agriculture, the Department of Commerce, the Department of Energy, the Department of Homeland Security, the Office of the Director of National Intelligence, the Joint Chiefs of Staff, the National Aeronautics and Space Administration, or their designated representatives, and the heads of other executive departments and agencies (agencies) invited by the Co-Chairs. The Administrator of the National Telecommunications and Information Administration shall serve as an ex officio member consistent with the Administrator's duties to advise the President on telecommunications and information policy issues.

(c) Components of the Executive Office of the President, including the Office of Management and Budget, the National Space Council staff, the National Security Council staff, the Office of Science and Technology Policy, and the National Economic Council staff, may participate by invitation of the Co-Chairs as observers and advise the Executive Committee on Presidential policy implications. The Chairman of the National Space-Based Positioning, Navigation, and Timing Advisory Board (or designated representative) shall be invited in an advisory role representing non-governmental considerations. The Co-Chairs may also invite the Chairman of the Federal Communications Commission to participate on the Executive Committee as appropriate. The Executive Committee shall convene at least once each year and as required on the advice of the Executive Steering Group, as described in Section 5(e).

(d) The Executive Committee shall make recommendations on sustainment, modernization, and policy matters regarding United States space-based PNT services to its member agencies, and to the President, through the Assistant to the President for National Security Affairs, or the Executive Secretary of the National Space Council, as appropriate. In addition, the Executive Committee will advise and coordinate with and among the agencies responsible for the strategic decisions regarding policies to maintain and improve United States leadership in the provision of space-based PNT infrastructures and services, including GPS, its augmentations and United States Government owned and operated space-based PNT systems and applications, security for these services, and their relationships with foreign space-based PNT services. Specifically, the Executive Committee shall:

(i) Ensure that national security, homeland security, and civil requirements receive full and appropriate consideration in the decision-making process and facilitate the integration and deconfliction of these requirements for space-based PNT capabilities, as required;

(ii) Coordinate individual Departments' and Agencies' space-based PNT program plans, requirements, budget considerations and policies;

(iii) Every four years provide the Executive Secretary of the National Space Council a report assessing current and planned civil space-based PNT services and whether they are projected to remain competitive with foreign space-based PNT services;

(iv) Promote, review, and implement plans to modernize United States space-based PNT infrastructure and services, including development, deployment, and operation of new or improved, or both, national security and public safety services;

(v) In coordination with the Office of Science and Technology Policy, promote research and development on next-generation technologies and on workforce development to ensure continued United States leadership in space-based PNT technologies;

(vi) Review proposals from and provide recommendations to agencies for international cooperation in coordination with the Department of State, as well as PNT spectrum management and protection issues in coordination with the Department of Commerce; and

(vii) Maintain and receive advice from the National Space-Based Positioning, Navigation, and Timing Advisory Board (Advisory Board). The Advisory Board shall be composed of experts from outside the United States Government, and shall be chartered as a Federal Advisory Committee. The Advisory Board shall seek input from state and local governments, industry, and academia on developments in the application of space-based PNT technologies and advise the Executive Committee on policy and service impacts.

(e) The Executive Committee shall maintain an Executive Steering Group composed of officials designated by the agencies that constitute the Executive Committee. The Executive Steering Group shall meet as needed to determine tasks and topics that require consideration of the Executive Committee. The agenda for Executive Steering Group meetings shall be approved by steering group members or their designees in advance. The Executive Steering Group, operating on a consensus basis, shall build consensus and work to resolve issues on behalf of the Executive Committee while establishing priorities and deconflicting tasks across the interagency members and the National Space-Based Positioning, Navigation, and Timing Coordination Office. When the Executive Steering group members cannot achieve consensus on proposals, budget recommendations, or policy, or in the event of critical events affecting United States space-based PNT architecture or services, the group shall recommend supplemental meetings of the Executive Committee to address relevant issues.

(f) The National Space-Based Positioning, Navigation, and Timing Coordination Office (NCO) shall support the meetings and functions of the Executive Committee and Executive Steering Group. It shall be led by a full-time Director assigned from the Senior Executive Service from an agency other than the Department of Defense, and include a Deputy Director assigned from the Department of Defense. Agencies represented on the Executive Committee shall assign staff to the NCO, as appropriate and consistent with applicable law, on a defined duration as required for task completion with appropriate technical expertise. The Executive Committee shall determine the resources for the NCO, including funding, location, staffing, and composition, consistent with this directive.

(g) The NCO shall serve as the Secretariat for the Executive Committee and shall perform functions delegated by the Executive Committee and Executive Steering Group. Agencies shall provide appropriate information to the NCO to ensure interagency transparency about space-based PNT programs, plans, policies, budget allocations, and activities affecting mutual interests or interagency dependencies. The NCO will coordinate the development and dissemination of strategic messaging and educational materials to support trust and adoption of United States space-based PNT services.

(h) The Executive Committee shall advise on and coordinate the interdepartmental resource allocation for GPS and its augmentations. The Secretary of Defense shall have primary responsibility for providing resources for development, acquisition, operation, sustainment, and modernization of GPS. The Secretary of Transportation shall continue to provide resources to the Secretary of Defense for assessment, development, acquisition, implementation, operation, and sustainment of GPS civil signal performance monitoring and any additional designated GPS civil capabilities that have exclusively civil (non-military) application consistent with interagency agreements. GPS augmentations and other unique PNT capabilities shall be funded by any agency requiring those services or capabilities, including out-year procurement and operations costs. Any new technical features proposed and funded by the civil agencies shall not unduly degrade or displace existing or planned national security functions of GPS. Resource issues will be resolved through the regular budget process.

(i) Within 120 days of publication of this directive, the Executive Committee shall publish an implementation plan to enact over a five-year period all provisions of this directive. Further, the Executive Committee will update the charter of both the Executive Committee, Executive Steering Group, and NCO consistent with the provisions within this Directive.

Sec. 6. Foreign access to United States Space-based PNT capabilities

(a) Exports of any United States PNT capabilities included on the United States Munitions List or the Commerce Control List will continue to be licensed pursuant to the International Traffic in Arms Regulations or the Export Administration Regulations, as appropriate, and in accordance with all existing laws and regulations. Export controls shall be updated to ensure that unnecessary controls that undermine or restrict the resilience and global use of civil GPS are reduced or eliminated without compromising United States navigation warfare, national security, or homeland security.

(b) As a general guideline, most exports of civil, mass-market space-based PNT capabilities that are currently available or are planned to be available in the global marketplace will continue to be considered favorably. Exports of sensitive dual-use or advanced PNT information, systems, technologies, and components will be considered on a case-by-case basis in accordance with existing laws and regulations, as well as relevant national security and foreign policy goals and considerations.

Sec. 7. Agency Roles and Responsibilities

Agencies shall allocate the resources required to fulfill the objectives of this policy, subject to the availability of funds appropriated for that purpose.

(a) The Secretary of State shall:

(i) In cooperation with the Secretary of Defense, the Secretary of Transportation and the heads of other appropriate agencies, promote the use of GPS and its augmentation services and standards with foreign governments and other international organizations, and encourage the development of foreign civil PNT services and systems based on GPS;

(ii) Take the lead for negotiating with foreign governments and international organizations regarding civil and, as appropriate and in coordination with the Secretary of Defense, military PNT matters, including coordinating interagency review of:

(A) Instructions to United States delegations for bilateral and multilateral consultations relating to the planning, management, and use of GPS, other global and regional navigation satellite systems, and their augmentation systems;

(B) International agreements, arrangements, and public statements with foreign governments and international organizations regarding the planning, operation, management, or use of GPS, other global and regional navigation satellite systems, and their augmentation systems; and

(iii) Participate with the Secretary of Defense in PNT dialog with allies, especially NATO relations.

(b) The Secretary of Defense shall:

(i) Have responsibility for the development, acquisition, operation, security, and continued modernization of GPS, while facilitating appropriate civil and homeland security representation and participation in these activities and any decisions that affect civil and homeland security equities;

(ii) Develop, acquire, operate, realistically test, evaluate, and maintain NAVWAR capabilities and other capabilities required to:

(A) Effectively utilize GPS services in the event of an adversary or other jamming, disruption, or manipulation;

(B) Develop effective measures to counter adversary efforts to deny, disrupt, or manipulate PNT services;

(C) Identify, locate, and mitigate, in coordination with other agencies, as appropriate, any intentional disruption or manipulation that adversely affects use of GPS for military operations;

(iii) Ensure the earliest operational availability for modernized military and NAVWAR capabilities;

(iv) Train, equip, test, and exercise United States military forces and national security capabilities in operationally realistic conditions that include denial or degradation of GPS. In cooperation with the Secretary of Transportation and the Secretary of Homeland Security, and as appropriate, with the Secretary of State, develop guidelines that facilitate these activities and NAVWAR training, testing, demonstrations, and exercises without unduly disrupting or degrading homeland security and civil services and operations, either internationally or domestically;

(v) Encourage use of GPS national security services by allied military forces to facilitate interoperability between United States and allied forces and capabilities, and to maintain their use as the pre-eminent military space-based PNT capability;

(A) Consistent with the guidance in Section 6 of this directive, make GPS national security services, user equipment, information, and technology available for use by allied military forces; and

(B) Work with allies to monitor access to national security services and user equipment to limit the potential for adversaries to use these capabilities against United States and allied military forces;

(vi) Maintain the commitment to discontinue the use of the feature known as Selective Availability;

(vii) In coordination with the Department of Transportation, maintain safety-of-life backwards compatibility commitments to enable continued international acceptance of civil and military GPS PNT services in civil airspace;

(viii) Facilitate access to appropriate levels of national security services and user equipment at the Federal level to meet critical requirements for emergency response and other homeland security purposes, and, on an exceptional basis, for civil purposes, including State or local emergency response in accordance with established memorandums of understanding;

(ix) Develop improved and dedicated national security PNT capabilities, including more diverse, flexible, and capable signals and services;

(x) In coordination with the Secretary of Transportation, provide estimates of GPS program costs based on the Department of Transportation’s strategy and future requirements to implement GPS data and signal authentication and reflect strategy consistent with the Federal Radio Navigation Plan or its successor;

(xi) Maintain lead responsibility for negotiating with foreign defense organizations for any cooperation regarding access to or information about GPS military services;

(xii) In cooperation with other agencies, as appropriate, assess the utility and feasibility of hosting secondary payloads on GPS satellites, including those intended to enhance global search and rescue capabilities for all users. No secondary payload may adversely affect the performance, schedule, or cost of GPS, or its signals or services. Resources required for the assessment, development, acquisition, integration, and operation of secondary payloads shall be the responsibility of the sponsoring agency or agencies; and

(xiii) In coordination with the Secretary of State and the Secretary of Commerce, and with all agencies who are members of the Executive Committee having been notified, maintain the Department of Defense’s lead responsibility for Radio Frequency compatibility coordination with other Radio Navigation Satellite Services (RNSS) who operate or intend to operate in the RNSS radio frequency bands utilized by GPS.

(c) The Secretary of Commerce shall:

(i) Promote United States industry access to foreign markets for space-based PNT goods and services while adopting a risk management approach to United States national security concerns;

(ii) Invest in research and development on next-generation technologies that could enhance GPS applications for commercial use;

(iii) Represent United States commercial interests with other agencies in the requirements review of GPS and its related augmentations;

(iv) In coordination with the Secretary of State, the Secretary of Defense, the Secretary of Transportation, and the Administrator of the National Aeronautics and Space Administration, seek to protect the radio frequency spectrum used by GPS and its augmentations through appropriate domestic and international spectrum management and regulatory practices;

(v) In coordination with the Secretary of Defense, the Secretary of Transportation, the Secretary of Homeland Security, and the Administrator of the National Aeronautics and Space Administration, facilitate cooperation between the United States Government and the United States private sector as appropriate to identify mutually acceptable solutions that will preserve existing and evolving uses of space-based PNT services, while allowing for the development of other non-interfering technologies and services that depend on use of the radio frequency spectrum;

(vi) In cooperation with the Administrator of the National Aeronautics and Space Administration, develop, and provide to the Secretary of Transportation, requirements for use of GPS and its augmentations to support civil space systems; and

(vii) In cooperation with the heads of other agencies, as appropriate, develop guidelines to improve the cybersecurity of PNT devices, including their capability to detect and reject manipulated or counterfeit signals, and promote the responsible use of space-based PNT services and capabilities for applications that support national security, economic growth, transportation safety, and homeland security as directed in Executive Order 13905.

(d) The Secretary of Transportation shall:

(i) Have lead responsibility for the development of requirements for civil applications from all United States Government civil agencies;

(ii) Ensure, in coordination with the Secretary of Defense and the Secretary of Homeland Security, the performance monitoring of United States civil space-based PNT services;

(iii) Consistent with the guidance in section 6 of this directive, and in coordination with the Secretary of State, facilitate international participation in the development of civil transportation applications using United States space-based PNT services;

(iv) Consistent with the background provided in section 3 of this directive, and in coordination with the Secretary of State and the Secretary of Defense, ensure that international transportation initiatives consider the dual-use nature of space-based PNT services, particularly including services that are openly available and can be readily used by adversaries or terrorists to threaten the security of the United States;

(v) Ensure, in coordination with the Secretary of Defense, that public safety service applications based on United States space-based PNT services meet or exceed internationally recognized standards as required to meet mission requirements, including those used for aviation, maritime, and surface transportation applications;

(vi) In cooperation with the heads of other agencies, as appropriate, promote the responsible use of United States and foreign civil space-based PNT services and capabilities for transportation safety as directed in EO 13905;

(vii) Represent the civil agencies in the development, acquisition, management, and operations of GPS and its augmentations;

(viii) In coordination with the Secretary of Defense and the Secretary of Homeland Security and the heads of other agencies, as appropriate, implement Federal and facilitate State, local and commercial capabilities to monitor, identify, locate, and attribute space-based PNT service disruption and manipulations within the United States that adversely affect use of space-based PNT for transportation safety, homeland security, civil, commercial, and scientific purposes;

(ix) Ensure the earliest operational availability for modernized civil signals and services on GPS and its augmentations, in coordination with the Secretary of Defense;

(x) In coordination with the Secretary of Defense, assess and assist, as appropriate, in the international acceptance of using the military PNT services of GPS for operations in civil airspace;

(xi) Facilitate international coordination for the development of monitoring standards for space-based PNT services;

(xii) Maintain awareness of the risks and potential benefits associated with the use of foreign space-based PNT services, and

(xiii) In coordination with the Secretary of Defense and the Secretary of Homeland Security, develop and validate requirements and a funding strategy to implement data and signal authentication of civil GPS and wide area augmentations for homeland security and public safety purposes consistent with the Federal Radionavigation Plan or its successor plan.

(e) The Secretary of Homeland Security shall:

(i) Identify space-based PNT requirements for homeland security purposes to the Secretary of Transportation;

(ii) In coordination with the Secretary of Transportation, and with the heads of other agencies, as appropriate, promote the responsible use of GPS and other PNT services, consistent with EO 13905;

(iii) In coordination with the Secretary of Defense and the Secretary of

Transportation, and in cooperation with the Secretary of Commerce:

(A) Ensure that mechanisms are in place to monitor, identify, locate, and attribute space-based PNT service disruptions and manipulations within the United States that can cause significant disruption to United States critical infrastructure and scientific purposes; and

(B) Develop procedures to notify the civil sectors and Federal, State, local, territorial and tribal agencies when space-based services have anticipated disruptions or are deemed to be no longer reliable.

(iv) In coordination with the Secretary of Defense, the Secretary of Commerce, and the Secretary of Transportation, develop and maintain capabilities, procedures, and techniques for, and routinely exercise, civil contingency responses to ensure continuity of operations in the event that access to GPS services are disrupted or manipulated;

(v) In coordination with the Secretary of Defense and the Secretary of Transportation, and in cooperation with the heads of other agencies, as appropriate, coordinate the use of existing and planned capabilities to identify, locate, and attribute any disruption or manipulation of GPS and its augmentations within the United States that significantly affects homeland security or critical infrastructure;

(vi) In coordination with the Secretary of Transportation, provide to the Executive Committee resourcing recommendations based on the Department of Transportation's strategy and future requirements to implement data and signal authentication and reflect that strategy consistent with the Federal Radionavigation Plan or its successor plan;

(vii) In coordination with the Secretary of Defense, the Secretary of Transportation, and the Director of National Intelligence, promptly notify the Secretary of Defense, the Administrator of the National Telecommunications and Information Administration, the Chairman of the Federal Communications Commission, the Director of National Intelligence, and the heads of other relevant agencies in cases of significant domestic or international disruption to or manipulation of United States space-based PNT services to enable appropriate investigation, notification, or enforcement action.

(f) The Director of National Intelligence shall identify, monitor, and assess the development of foreign threats to the use of GPS PNT architectures and related services, and provide information to assist the Secretary of Defense in development of countermeasures.

(g) The Administrator of the National Aeronautics and Space Administration shall:

(i) In cooperation with the Secretary of Commerce, develop and provide to the Secretary of Transportation technical requirements for the use of GPS and its augmentations to support civil and commercial space systems;

(ii) In cooperation with the Secretary of Defense, the Secretary of Commerce, and the Secretary of Transportation, develop requirements for GPS support of space operations and science in higher orbits within the SSV and beyond to cislunar space; and

(iii) In cooperation with the Secretary of State, the Secretary of Defense, the Secretary of Commerce, and the Secretary of Homeland Security, sustain and modernize search and rescue and distress alert and location capabilities and programs that operate as secondary payloads on GPS satellites.

Sec. 8. Notification of harmful disruption or manipulation

Agencies detecting or receiving domestic or international reports of harmful disruption or manipulation of United States space-based PNT services shall provide timely reports to the Secretary of Homeland Security, the Secretary of Defense, the Secretary of Transportation, and the Director of National Intelligence. Upon notification:

(a) The Secretary of Commerce, and the Chairman of the Federal Communications Commission in cooperation with the heads of other agencies as appropriate, shall take appropriate and legally permissible actions required to mitigate harmful disruption or manipulation of United States space-based PNT services within the United States.

(b) The Secretary of State shall, as appropriate, notify or coordinate the notification of foreign governments and international organizations in the event of harmful disruption or manipulation of United States space-based PNT services caused by foreign government or commercial activities.

(c) The Secretary of Homeland Security, when appropriate, shall notify the civil sectors and United States Government agencies of the disruption.

Sec. 9. General provisions

(a) Nothing in this directive shall be construed to impair or otherwise affect:

(i) the authority granted by law to an executive department or agency, or the head thereof; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(b) This directive shall be implemented consistent with applicable law and subject to the availability of appropriations.

(c) This directive is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable as law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

Source: https://trumpwhitehouse.archives.gov/presidential-actions/memorandum-space-policy-directive-7/

ICAO Council makes progress on new RPAS standards

During its ongoing 222nd Session, the ICAO Council has adopted new and amended Standards and Recommended Practices (SARPs) driving important progress on the international safety and interoperability of remotely piloted aircraft systems (RPAS).

The new provisions will become effective on 12 July 2021, and applicable as of 26 November 2026. The most important pertain to Annex 8 — Airworthiness of Aircraft to the Chicago Convention, and cover certification requirements for remotely piloted aeroplanes and helicopters, in addition to the remote pilot stations (RPS) they are operated from.

"This provides a baseline of requirements which countries can employ in the near term to certify RPAS for international cargo operations or aerial work. Future work will address passenger-carrying RPA, as well as more advanced capabilities being anticipated for future urban air mobility."

The new Annex 8 SARPs were complemented by new provisions adopted by the Council on C2 Links, the data links that connect the RPA and RPS, in Annex 10 to the Convention, on Aeronautical Telecommunications. They include Amendment 90 to Volume V, which addresses spectrum allocations that may be used for RPAS C2 Links, and the adoption of an entirely new Volume VI, on RPAS C2 Link communications systems and procedures.

A second package of C2 Link SARPs, which is currently being developed by ICAO's RPAS Panel, will address details for interoperability, spectrum utilization, and compatibility with existing communications and navigation systems, including the sharing of the proposed frequency bands.

The latest RPAS progress required minor modifications to Annexes 1 (Personnel Licensing) and 2 (Rules of the Air) of the Convention, and will eventually be supported by more substantial Annex 2 changes already in development. Previous Annex 1 Standards adopted by the Council in 2018 introduced a regulatory structure for the issuance of remote pilot licences for applicability as of November 2022.

As this extensive work continues through ICAO, it is presumed that all of the 19 Annexes to the Chicago Convention will eventually require either significant or minor modification to achieve the safe, secure and efficient integration of RPAS into current global aviation frameworks. *www.icao.int*

FAA new drone rules take effect

According to the press release issued by Federation Aviation Administration (FAA), final rules take effect on April 21, 2021 for remotely identifying drones and allowing operators of small drones to fly over people and at night under certain conditions.

"Today's rules are an important first step in safely and securely managing the growing use of drones in our airspace, though more work remains on the journey to full integration of Unmanned Aircraft Systems (UAS)," said U.S. Secretary of Transportation Pete Buttigieg. "The Department looks forward to working with stakeholders to ensure that our UAS policies keep pace with innovation, ensure the safety and security of our communities, and foster the economic competitiveness of our country."

"Drones can provide virtually limitless benefits, and these new rules will ensure these important operations can grow safely and securely," said FAA Administrator Steve Dickson. "The FAA will continue to work closely with other Department of Transportation offices and stakeholders from across the drone community to take meaningful steps to integrate emerging technologies that safely support increased opportunities for more complex drone use."

The Remote Identification (Remote ID) rule provides for identifying drones in flight and the location of their control stations, reducing the risk of them interfering with other aircraft or posing a risk to people and property on the ground. The rule provides crucial information to our national security and law enforcement partners and other agencies charged with ensuring public safety. It applies to all drones that require FAA registration.

The Operations Over Peoplerule applies to pilots who fly under Part 107 of the Federal Aviation Regulations. Under this rule, the ability to fly over people and over moving vehicles varies depending on the level of risk (PDF) a small drone poses to people on the ground. Additionally, this rule allows operations at night under certain conditions provided pilots complete certain training or pass knowledge tests.

The public can review both the Remote ID (PDF) and Operations Over People Rule (PDF) in the Federal Register. *www.faa.gov*

EC adopts the U-Space package: towards a safe drone integration into U-Space

On April 22, the EC adopted the U-Space package – three regulations that oversee drone integration and manned aircraft activity in U-Space. Together with last December's "Sustainable and Smart Mobility Strategy", this milestone achievement will pave the way for safe integration of drones and UAS in urban airspace, and even BVLOS operations. The U-Space package is just one of the many initiatives the European Union has undertaken towards drone integration.

The adoption of the U-Space package gives framework to drone operativity in urban airspace. Nonetheless, there are several steps to take before complete RPAS integration in civil air space. The U-Space package is a product of years of strategic planning. In 2015, the EU called for the development of a basic legal framework for safe drone operations. With today's adoption of the regulatory framework for U-space, the Commission finally fulfilled the objectives set in 2015. *https://ec.europa.eu*

Satellite imagery reveals three decades of coastal change

The evolution of Australia's coastlines can now be seen in unprecedented scale and detail, via a new tool developed by Geoscience Australia's Digital Earth Australia (DEA) program.

Using satellite imagery collected since 1988, DEA Coastlines maps annual changes to Australia's coastlines to highlight long-term trends in coastal erosion and growth.

The free online tool can also illustrate how natural coastal features like sandbanks or river mouths shift and change over time.

Geoscience Australia's National Earth and Marine Observations Branch Head Maree Wilson said DEA Coastlines provides scientists, managers, and policymakers with new information to maintain and protect Australia's iconic shores for future generations.

"Australia has a highly dynamic coastline of over 30,000 kilometres with many unique environments: sandy beaches, rocky cliffs, muddy tidal flats, and mangroves. DEA Coastlines is the first nationally consistent dataset within Australia that tracks these changing shorelines," Ms Wilson said.

"Understanding how our coastal environments have been historically affected by pressures such as extreme weather, sea level rise and human development is vital to managing our coastlines now and into the future."

DEA Coastlines uses world-leading techniques to combine satellite data with tidal modelling to map the location of the coastline at mean sea level each year, showing changes along our coastlines at an unprecedented scale.

The rise and fall of the tide along Australia's coast dramatically affects the position of the shoreline, making it difficult to separate long-term coastal change from the short-term effect of tide.

This is particularly the case in locations like north-west Australia's Kimberley region, where tides can rise by up to 11 metres, potentially shifting the position of the shoreline by tens or hundreds of metres.

By accounting for tide, the DEA Coastlines method produces coastlines and rates of coastal change that can be compared consistently across time, and between different coastal locations and environments along Australia's coastline.

DEA Coastlines also uses an advanced subpixel mapping method that uses subtle differences in the "wetness" of each satellite pixel to draw out high resolution coastlines from lower resolution satellite imagery.

This means the tool is accurate down to 10 metres – and able to detect coastal change as small as 2.9 metres in certain coastal locations. Previous global mapping was limited to 30-metre resolution.

DEA Coastlines also draws on nearly 58,000 independent measurements of coastline positions across Australia to ensure the accuracy of its mapping.

"Geoscience Australia worked extensively with local councils, state governments, academia and citizen scientists to ensure the tool will help them reliably assess impacts to our precious coastlines and plan for the future," Ms Wilson said.

Geoscience Australia's Digital Earth Australia program puts insights from satellite data into the hands of more Australians, driving innovation for a more productive and sustainable future.

The DEA Coastlines tool is available to explore on the interactive DEA Maps platform.

DHS publishes free resources to protect critical infrastructure from GPS spoofing

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) announced today it has published the Positioning, Navigation, and Timing (PNT) Integrity Library and Epsilon Algorithm Suite to protect against Global Navigation Satellite System (GNSS) spoofing, or deceiving a Global Positioning System (GPS) device through false signals. These resources advance the design of PNT systems and increase resilience of critical infrastructure to PNT disruptions.

PNT services, such as GPS, are a national critical function that enable many applications within the critical infrastructure sectors.

The PNT Integrity Library and Epsilon Algorithm Suite address this issue by providing users a method to verify the integrity of the received GPS data.

The PNT Integrity Library and Epsilon Algorithm Suite are open source and available free of charge. *www.dhs.gov*

NIST finalizes cybersecurity guidance for PNT systems

As part of an effort to help users apply its well-known Cybersecurity Framework (CSF) as broadly and effectively as possible, the National Institute of Standards and Technology (NIST) has released finalized cybersecurity guidance for positioning, navigation and timing (PNT) services.

Formally titled Foundational PNT Profile: Applying the Cybersecurity Framework for the Responsible Use of Positioning, Navigation and Timing (PNT) Services (NISTIR 8323), the document is part of NIST's response to the Feb. 12, 2020, Executive Order 13905, Strengthening National Resilience Through Responsible Use of Positioning, Navigation, and Timing Services. To develop the profile, NIST sought public input regarding the general use of PNT data before releasing a draft version in October 2020. The finalized version reflects public comments NIST received on the draft.

The "profile," a term NIST uses to describe the application of the CSF to a specific implementation scenario, is intended to help mitigate the cybersecurity risks that confront PNT services. These services are important to national and economic security and include the Global Positioning Systems that are widely used by smartphone-based navigation apps, as well as split-second timing technologies that enable stock trading and efficient control of the power grid.

The main addition since the draft version was released is a "Quick Guide" intended to offer users an easier way to get started using the profile.

IT personnel might appreciate the extensive set of references the authors have included. These range from guidance already published by both government and private sector entities to academic papers and other technical sources. *www.nist.gov*

EU should make better use of its space assets

The European Union has not done enough to capitalise on its 18 billion euro ($21.6 billion) space programmes, including its Galileo satellite positioning system and Copernicus observation satellites, according to EU auditors.

The European Court of Auditors (ECA) found that the EU had failed to spell out the societal and economic benefits of its space programmes, or set clear targets or timeframes to achieve those benefits.

"Technologically, the EU has succeeded in becoming a global player in terms of space-based earth observation and navigation services. But the EU lacks a comprehensive approach for supporting the uptake of its space services to fully capitalise on the significant public investment made," said Mihails Kozlovs, the ECA member responsible for the report.

The EU has spent 18.3 billion euros up to the end of 2020 and has earmarked more than 14 billion euros for the 2021-2027 period. The biggest share of that investment is on Copernicus and Galileo, the two flagship satellite systems.

Copernicus was put to good use monitoring some EU policies, in agriculture, climate and maritime surveillance for example, the auditors said. But EU-wide use of its observation data remains restricted to scientists and experts, even though access to it was improved.

The Galileo programme, which has 26 satellites in orbit to provide an alternative to the U.S. GPS positioning system, was initially delayed by eight years when it began operating in 2016.

The auditors said progress had been made in introducing Galileo-compatible receivers, allowing it to be used in smartphones or cars. But it still lags the U.S. GPS system, and auditors said it will take time until Galileo is used more widely. *www.reuters.com*

NTIPRIT conducts webinar on NavIC

National Telecommunications Institute for Policy Research, Innovation and Training (NTIPRIT), the apex training institute of Department of Telecommunications, Government of India conducted a webinar on April 28, 2021 on the topic "NavlC — Opportunities for the Telecom Industry" in collaboration with ISRO and Telecom Industry.

The webinar was inaugurated by Shri Anshu Prakash, Union Telecom Secretary and Chairman Digital Communications Commission (DCC). The inaugural session was also addressed by Shri K Ram Chand, Member (Technology), Digital Communications Commission (DCC), Sh. R Umamaheswaran, Scientific Secretary, ISRO, and Sh. U.K. Srivastava, Sr DDG, NTIPRIT.

Sh. R Umamaheswaran, Scientific Secretary, ISRO briefed about the NaviC system and informed that it has higher accuracy than the peer systems. He further informed that there are plans to make NavIC available on L-1 band in addition to the presently used L-5 band. He felt that the NavIC system should be made mandatory for mobile phones released in Indian markets to adopt.

Shri Anshu Prakash, Union Telecom Secretary and Chairman DCC, while formally launching the webinar, underscored the importance of integration of technology with applications so as to reap the benefits of technology to the fullest. He supported the views of Sh. R Umamaheswaran for making NavlC mandatory for all mobile phones in India. Secretary (Telecom) also stressed the use of tracking potential of NavIC in the present Covid pandemic in tracking the oxygen tankers and other essentials. He also appreciated the efforts of telecom industry, including that of chipset and handset manufacturers in their efforts to adopt the NaviC service. *www.pib.gov.in*

Post-Brexit loss of shipping positioning systems alerts

On 1 January 2021, the UK's Brexit transition period ended and it left the EU after years of negotiations between London and Brussels. The effects of the country's "divorce" from the Union have been felt everywhere, in economic and socio-political terms.

As for shipping, Brexit was felt not only by UK ports with regards to fishing rights but it will also impact navigation systems.

As per Brexit accords, the UK is no longer participating in European satellite-based navigation systems such as Galileo and EGNOS and, from 25 June, will not receive access to EGNOS Safety of Life services when it's rolled out, meaning mariners will not receive a signal whenever positioning, navigation and timing (PNT) systems suffer degradation.

According to George Shaw, principal development engineer at the UK General Lighthouse Authorities, this could cause problems both for mariners and ships. "We're getting into more complex sea spaces, particularly around the UK, and the need for integrity is fundamental," he says.

"The EGNOS system is one of the components that helped provide integrity for positioning."

The European Geostationary Navigation Overlay Service (EGNOS) is the first pan-European satellite navigation system. It augments the US GPS satellite navigation system and makes it suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels.

Developed by European agencies such as the European Space Agency, the European Commission and Eurocontrol in 1998, EGNOS functions through a system of three geostationary satellites. Linked to a network of stations, EGNOS transmits a signal that contains information on the reliability of the information sent by the GPS, allowing for more accurate positioning.

"We need warnings to be reliable," explains Shaw. "It's a bit like crying wolf; if you cry wolf too often falsely, then you start to disbelieve the warnings. Integrity is like that you need to be able to trust that the warnings are real."

In crowded sea spaces, false positioning could become a big issue, for mariners and vessels alike.

"With UK shipping passages getting rapidly busier and more constrained due to increases in traffic, ship size, offshore installations, environmentally sensitive areas, and blue economy uses such as aquaculture, ships will need more trustworthy and reliable PNT to enable high-precision navigation," he adds.

"With seaborne trade set to double by 2030, the precision of position and timing data will become even more pivotal to the speed and efficiency of trade flows and help avoid widespread slowdown and disruption to our trade.

Even though they are aware of the threat to the availability of GNSS and other PNT systems, mariners are usually less aware of the threat to the integrity of GNSS, which could hinder their safety.

"The guarantees that the EGNOS Safety of Life services provide give that confidence to mariners in being able to use the system," he says. "We're talking about potentially small errors in crowded sea spaces that can provide risks to navigation and take the vessel closer to danger."

"Having precise systems like GPS is creating a temptation for mariners to sail safely but more closely to danger and therefore having an understanding of the likely uncertainties of positioning is becoming increasingly important."

What will change for British ships after 25 June is that even though will still be able to receive EGNOS signals, they will no access to assurances provided by the EGNOS Safety of Life Services.

"Integrity needs to be assured at the user level as well as the system level," says Shaw. "This includes the system being able to detect and provide timely warnings to the user when it must not be used for the intended purpose."

"Users must also be warned in a timely manner about any errors in the data incurred locally that impact its use for the intended purpose."

To ensure that positioning systems are correct, Shaw says there are a few solutions.

"The UK now recognises the need for a 'backstop' to augment GNSS data and warn mariners when GNSS data is erroneous," he concludes. "The key is a mix of space-based and terrestrial solutions that not only provide round-the-clock availability of PNT data but also ensure that users can trust the correctness of that data, and act on it with confidence, by ensuring they have integrity at their core." *www.ship-technology.com*

Trimble and Amberg Announce Tunnel Construction Survey Solution

Trimble and Amberg collaborate to increase productivity in underground construction with Amberg Tunnel Software and Trimble S Series Robotic Total Stations and Data Collectors.

This solution enables tunnel construction surveyors to efficiently perform tasks such as excavation guidance, as-built control, automated survey and stakeout design information.

The ADE robotics project carries out the final field tests

After nearly two years of work Bremen in Germany hosted from 18 March to 16 April the final tests of the ADE (Autonomous DEcision Making in very long traverses) space robotics project from 15th of March to 16th of April, rescheduled from the initially-intended venue of Fuerteventura due to COVID-19 travel constraints.

ADE falls within the Strategic Research Cluster (SRC) in space robotics technology, coordinated by the H2020 PERASPERA project. Its remit is to develop and test a planetary rover system with very long traverse capabilities by independently taking the decisions required to progress, reduce risks and seize opportunities of data collection.

Coordinated by GMV and run with the collaboration of 13 partners from all over Europe, ADE is dedicated to autonomous robotic decision-making, targeting specifically surface robot planetary missions performing very long traverses in unknown environments. ADE draws on the ERGO (European Robotics Goal-Oriented Autonomous Controller) autonomy system developed under GMV leadership in the first SRC phase.

The robotics platform used for field testing the project's technology was the SherpaTT rover developed and provided by the Robotics Innovation Center of the German Research Center for Artificial Intelligence (DFKI). SherpaTT is a desert veteran that has already carried out simulated space missions in the Utah desert (USA) and Morocco under the GMV-led ERGO project, in 2016 and 2018, respectively.

Preliminary tests were held in November 2020 to February 2021 in a 7m x 7m indoor sandbox at DFKI premises in Bremento validate most of the onboard systems: localization, perception, guidance, manipulation of the robotic arm in motion, FDIR (Fault Detection, Isolation and Recovery), dynamic planning, and science agent. After gaining excellent results there, ADE moved on to final planetary exploration tests in a custom-built terrain comprising diverse obstacles and compacted sand.

For 5 weeks the robotic technology was put through its paces, testing navigation autonomy using the perception and localization cameras, sample-collection and -depositing with the robotic arm, automatic goal-oriented mission planning (travel to a fixed point, carry a sample from one point to another, move on to an image-taking point), plus the possibility of ad hoc scientific target recognition as the opportunity arises.

ADE came through the tests with flying colors, pulling off a long and totally autonomous traverse of almost 500m with the rover SherpaTT in a record time of less than three hours. The system incorporates all technological components developed in the previous SRC phase.

The technology developed under ADE is designed to meet future space exploration rover needs. Its goal-oriented autonomy system, apt for various space robots, can also be deployed on the ground for robots working in harsh environments, e.g., nuclear plants, rescue operations, or oil & gas industry.

Transdisciplinary Research for Pathways to Sustainability Awards

The Group on Earth Observations (GEO) together with Belmont Forum, Future Earth and twelve funding partners announced 13 new awards funded under the multilateral, transdisciplinary Collaborative Research Action focusing on "Transdisciplinary Research for Pathways to Sustainability".

The call supports the establishment of collaborative networks to develop innovative solutions for sustainable development pathways. The funded networks seek to assess the positive and negative connections between the economy, technologyand institutions with the environment, climate, biodiversity and human well-being to understand possible pathways to a sustainable world. A critical focus of these networks is the co-production of knowledge and solutions using a transdisciplinary approach. This includes engagement of societal stakeholders to ensure ownership of research outcomes, relevance to decision makers, societal acceptance and empowerment.

Fourteen funders, including GEO, have pledged 2.5M€ of financial and in-kind resources to support 13 research networks with 136 collaborators from 37 countries over the next 2 years. The teams will focus on sustainability challenges in the Americas, Africa, Asia, and Europe. Through the generous support and partnership of FutureEarth Africa, AllEnvi, NIMR, NRF and GEO, a new milestone will be reached: 28% of the collaborators supported through this Belmont Forum call are from African Nations.

GEO will provide in-kind support to two projects that are building their transdisciplinary research on Earth observations:

- COVPATH - Coviability Path, a new framework to sustainably link humankind and the biosphere.

COVPATH proposes a new transversal pathway in the sustainable development agenda that reintegrates humans into the living world around shared health. This project builds on the socio-ecological concept of coviability, defined as the interdependence between humans and nature that results from interactions between human and non-human systems and is based on mutual sustainability. Viability is defined as the ability to exist, thrive, feel good, and be happy in a sustainable way. COVPATH will test the implementation of this concept in six biosphere reserves spread across the globe. Geo-indicators of co-viability will be created using open Earth observations available through the Global Earth Observation System of Systems (GEOSS) and will benefit from collaboration with the GEO BON and EO4SDG initiatives.

- SUSTAINDAM - Sustainable management and planning of hydropower generation in West Africa under climate change and land use/land cover dynamics.

SUSTAINDAM aims to contribute to sustainable planning and management of hydropower generation in West Africa under climate uncertainties and land use/land cover dynamics. The research team plans to build communities of practices with stakeholders to explore trade-offs across multiple SDGs that may be required in terms of effective hydroelectric power generation. The added value this project brings through the integration of natural and social sciences will inform dam management by providing an interdisciplinary understanding of trade-offs related to vulnerability reduction, societal adaptation, mitigation, and transformation in relation to local and national water governance. 4 hydro-electric dam sites across West Africa will be compared with different socioeconomic contexts considering climate change scenarios. SUSTAINDAM will collaborate directly with AfriGEO, the regional GEO, which is a member of the consortium. The proposed consortium consists of 14 partners, including four from African institutions, nine from European institutions (two from France and seven from Germany), and one regional organization in Kenya (AfriGEO).

The two winning projects will have access to the GEO network, resources and stakeholders of selected GEO Work Programme activities with the aim of integrating, supporting, or scaling-up the work of these GEO activities. The GEO Secretariat will liaise with winning projects that qualify for GEO resources. *www.earthobservations.org*

RACELOGIC Officially 'One to Watch'

RACELOGIC, the company behind LabSat, has been named as one of the '10 Ones to Watch' in the 22nd annual Sunday Times BDO Profit Tracker 100, which ranks Britain's top private companies.

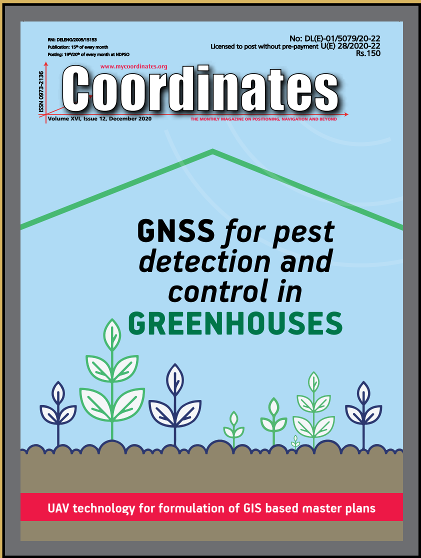
The 10 Profit Track Ones to Watch represents a cross-section of companies that have achieved or predict good profit growth. In addition to profit performance, the assessment for inclusion is also based on factors such as resilience in the face of the pandemic and strength of business model.

Graham Mackie, CEO of RACELOGIC was delighted to see the hard work of his team recognised by industry experts: 'In a challenging year, we are proud of our performance and the way in which every member of the team at RACELOGIC has adapted to new ways of working and serving our customers.'

The Buckingham based business sells to over 100 countries and generated 88% of its sales overseas last year. 'We have great products that service a global market which provided some resilience to the impact of the pandemic. We are continuing to develop cutting-edge technology which is enabling us to diversify into new sectors including the film and gaming industry.'

The sales growth and addition of new products has resulted in RACELOGIC expanding its workforce at a time when many are having to reduce staff numbers. 'We are currently recruiting for a range of engineering and administrative positions, all of which can be found on our website. It is an exciting time to join RACELOGIC and perhaps even more so now that we are officially 'one to watch'!'.

The 10 Profit Track Ones to Watch finalists will be judged by Stuart Lisle, senior tax partner at BDO and Hamish Stevenson, founder of Fast Track, and the winner will be announced at the Profit Track 100 virtual awards event in June. *www.racelogic.co.uk*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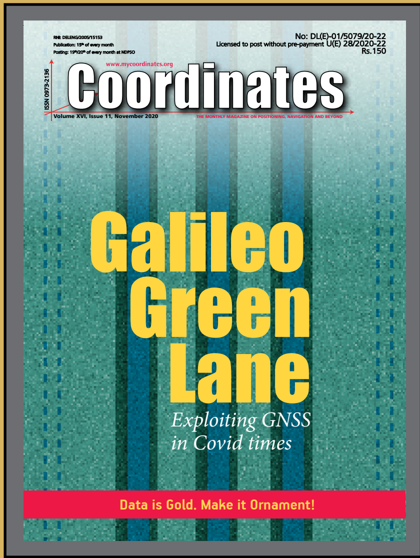
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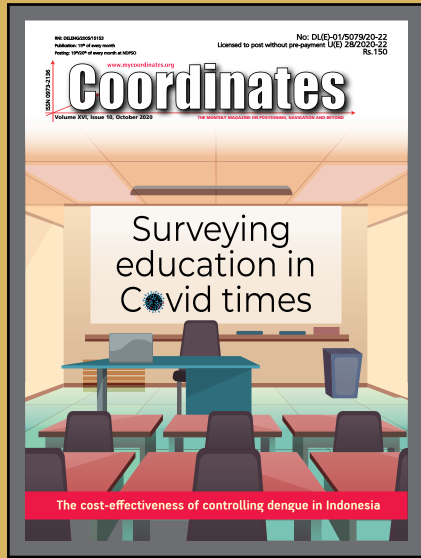
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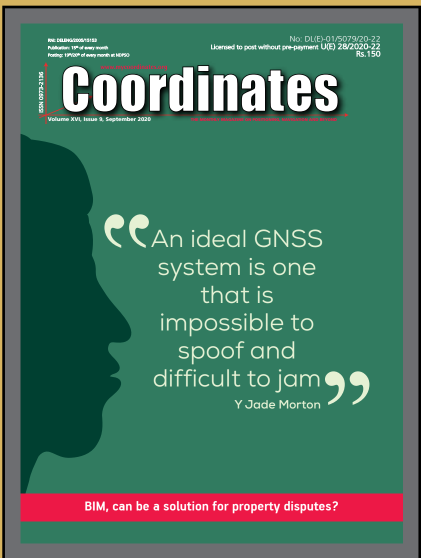
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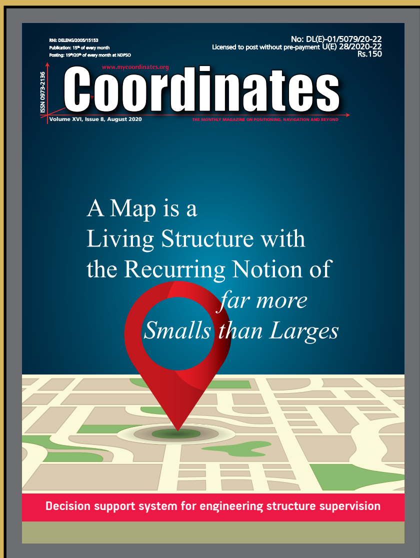
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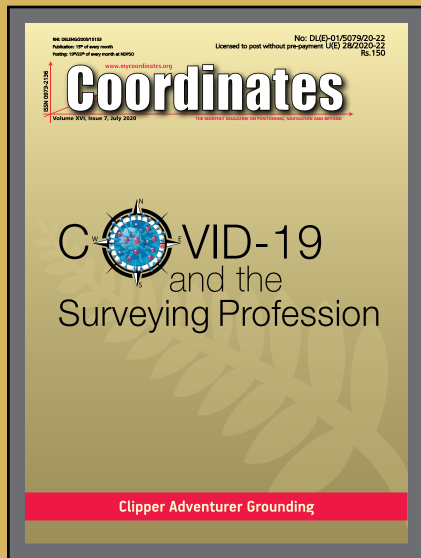
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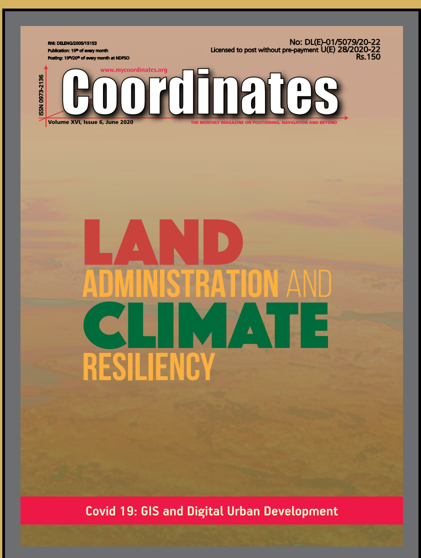
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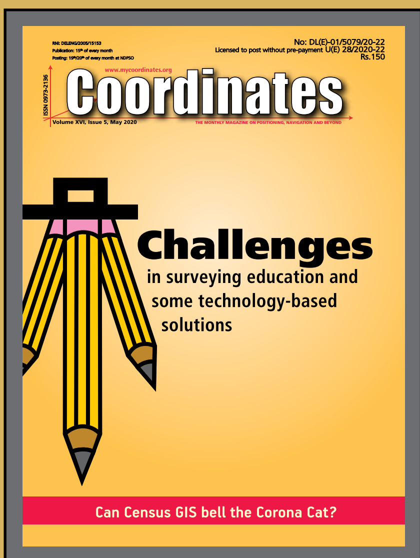
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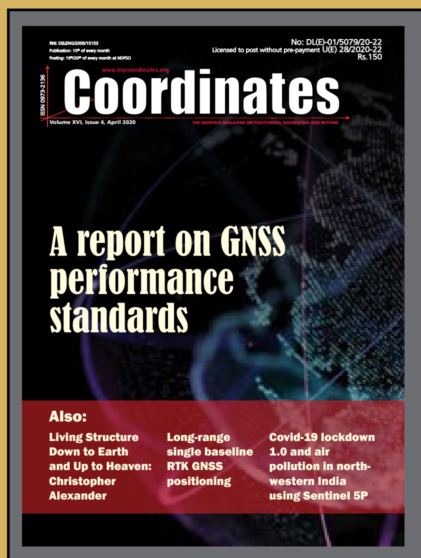
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