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SPACE SITUATIONAL AWARENESS USING DECONSTRUCTED BLOCKCHAIN TECHNOLOGY

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Presented by: Waqar Zaidi, Lead, Systems Engineering, Space Domain Awareness, L3Harris

Key Definitions



Emergence

When an entity is observed to have properties its parts do not have on their own, properties or behaviors which emerge only when the parts interact in a wider whole.

Etiology

The study of the causes, origins, or reasons behind the way that things are, or the way they function, or it can refer to the causes themselves.

Spontaneous Order

Groups of human beings, left free to each regulate themselves, tend to produce spontaneous order, rather than the meaningless chaos often feared.

Worldwide SSA Requires Strong Decentralized, Native, and Independent Nodes

Space Situational (Domain) Awareness Impasse



Commercial &
Academia

“Bringing together operators’ data and observations of their own spacecraft with observation from telescopes and radar, that’s the holy grail” – AGI

“One of the biggest hurdles in making space transparent and predictable is sharing of observational data” – Dr. Moriba Jah

SPACENEWS

Data sharing seen as c **SPACENEWS**
awareness

by Jeff Foust — September 20, 2019



Op-ed | To deter attacks on satellites, U.S. needs a strategy to identify bad actors

by John Klein — June 5, 2020



The 4 V's of Space Situational Awareness Data **Validation**

Veracity?

Variety?

Volume?

Velocity?

DoD

“DoD should investigate and better understand how to keep forensic data pristine, or uncorrupted, so that the validity of data and information is not called into question.” – John Klein

“A credible and trusted attribution process underpins a successful deterrence strategy.” – John Klein

Worldwide Space Situational (Domain) Awareness is a Difficult Problem to Solve

High Risk Debris-on-Debris Low Earth Orbit Conjunction in the News



LeoLabs, Inc.
@LeoLabs_Space

We are monitoring a very high risk conjunction between two large defunct objects in LEO. Multiple data points show miss distance <25m and Pc between 1% and 20%. Combined mass of both objects is ~2,800kg.

Object 1: 19826
Object 2: 36123
TCA: Oct 16 00:56UTC
Event altitude: 991km

6:42 PM · Oct 13, 2020 · TweetDeck

Commercial SDA Data Provision Requires Provenance, Attribution, Validation and Trust

Multiple Decentralized Sources Trying to Achieve Consensus



**MULTIPLE SOURCES SAY
TWO SATELLITES
IN POSSIBLE COLLISION
NEW VISUALIZATION**

LeoLabs, Inc. @LeoLabs_Space
We are monitoring two large defunct objects in LEO. Multiple data points show miss distance <25m and Pc between 1% and 20%. Combined mass of both objects is ~2,800kg.
Miss Distance < 25m

Moriba Jah @moribajah
Here is our @Ode conjunction of COSMOS 2004 (19826) and CZ-4C R/B (32290). TCA: 2020-10-16T00:56:40.730 Miss Distance: 69.9 meters Relative Velocity: 14659.19 meters/sec The primary body is assumed to be COSMOS 2004. Covariance...
Miss Distance ≈ 70m

Kayhan Space @KayhanSpace
We're monitoring a analysis between two objects, Object 1: 36123 (CZ-4C R/B) & Object 2: 19826 (COSMOS 2004).
Time of Closest Approach (TCA) 2020-10-16T00:56:41.310 UTC
Miss Distance ≈ 424m

Jonathan McDowell @planet4589
Data source: Replying to @planet4589
Here's my own visualization of the encounter. Kosmos-2004 (red) is heading south towards the pole, CZ-4C-Y4 (purple) is heading north towards the Falklands
Miss Distance ≈ ??

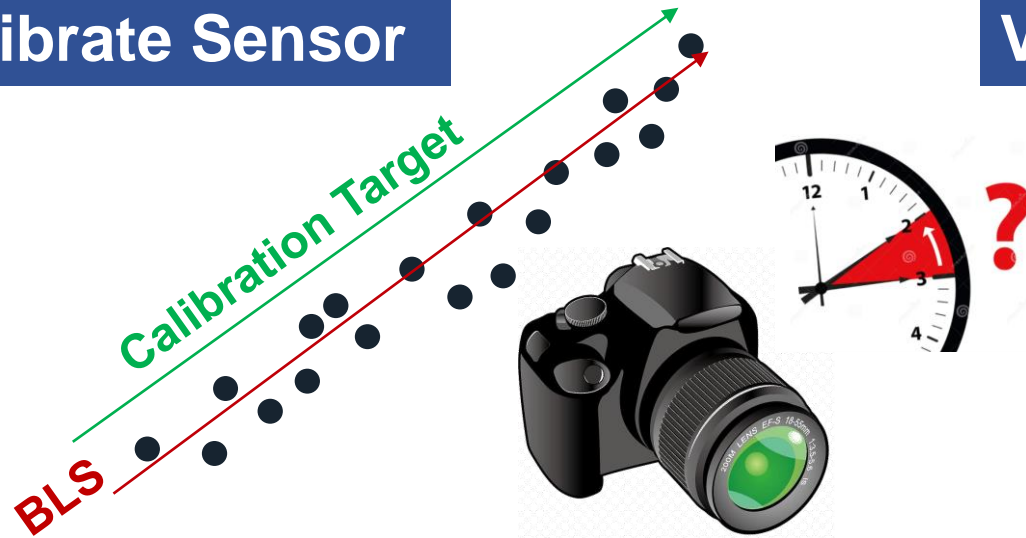


Decentralized Space Domain Awareness Needs an Official Regulated Medium to Proliferate

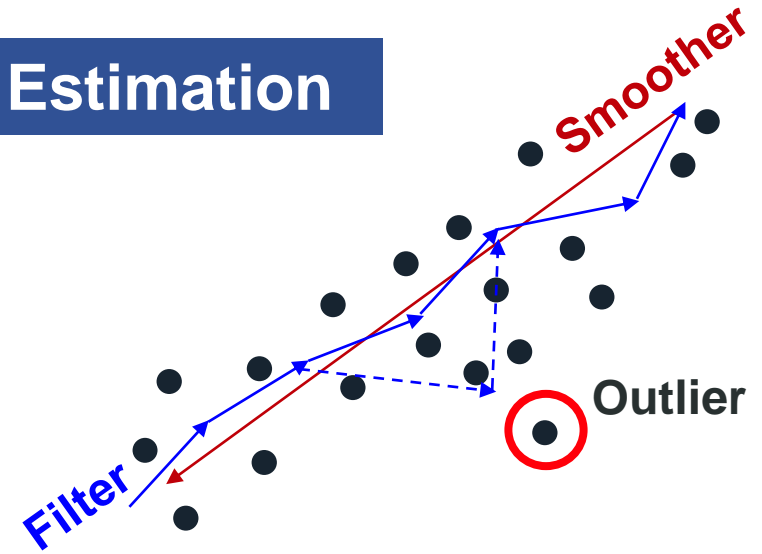
How Do You Methodically Validate a Conjunction?



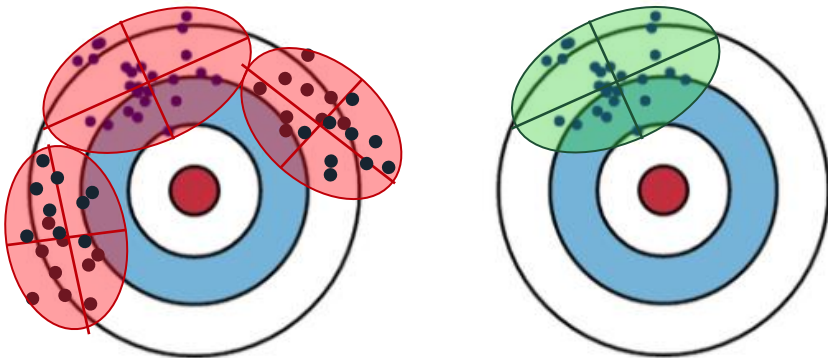
Calibrate Sensor



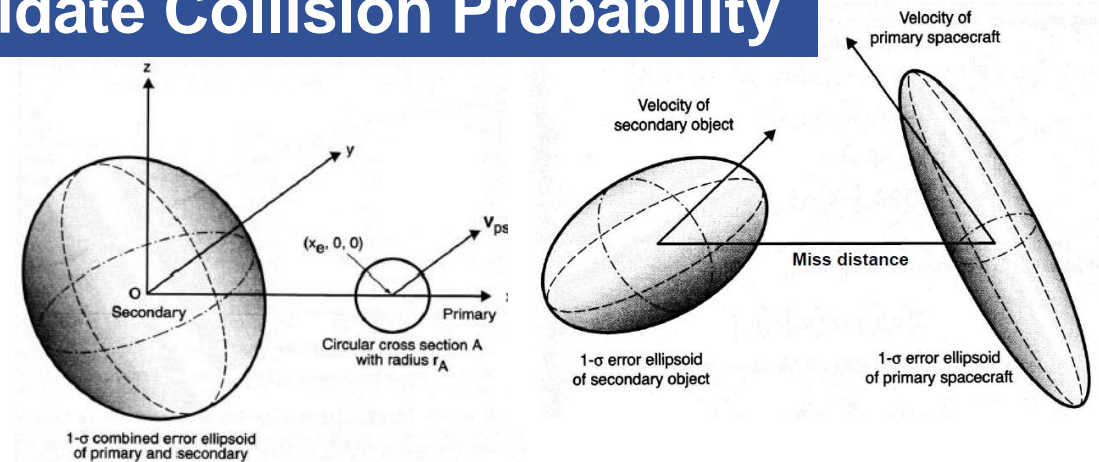
Validate Estimation



Quantify Uncertainty



Validate Collision Probability



Sample Pool of SDA Data Users, Providers, and Curators



Data Users



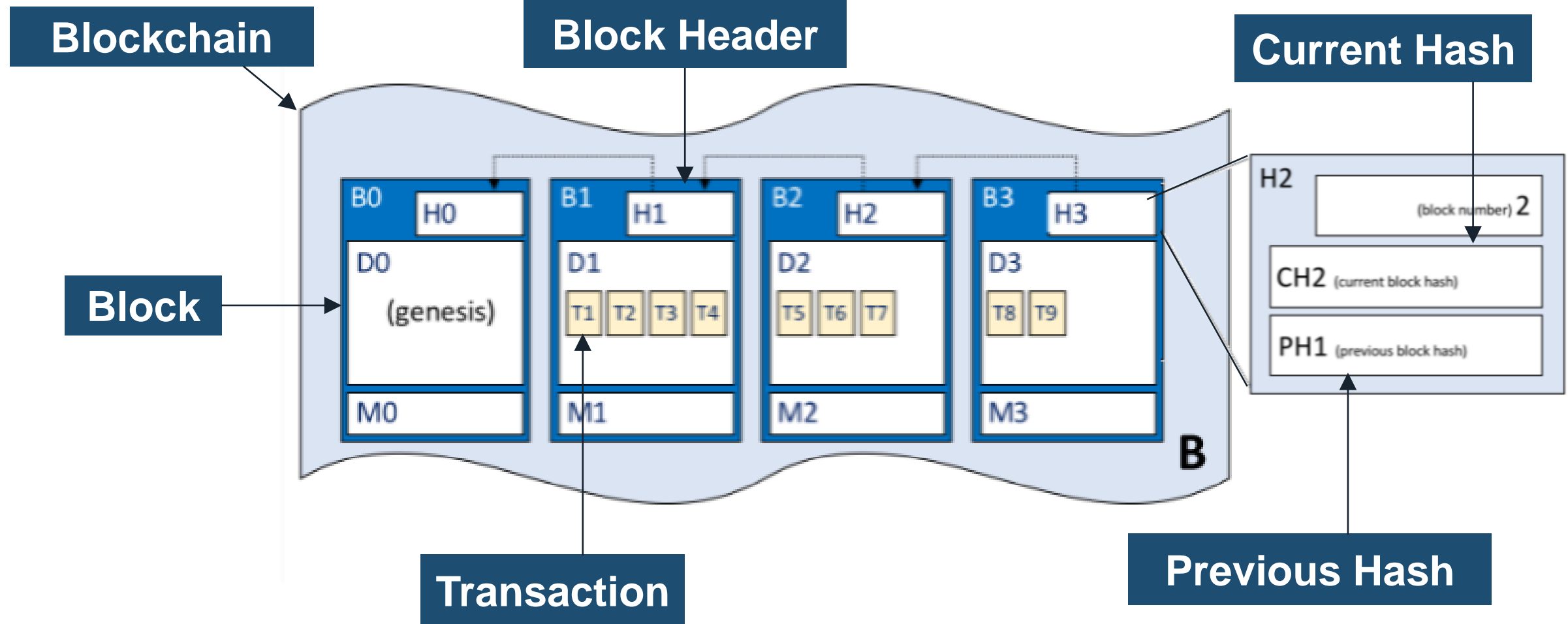
Data Providers



Data Curators

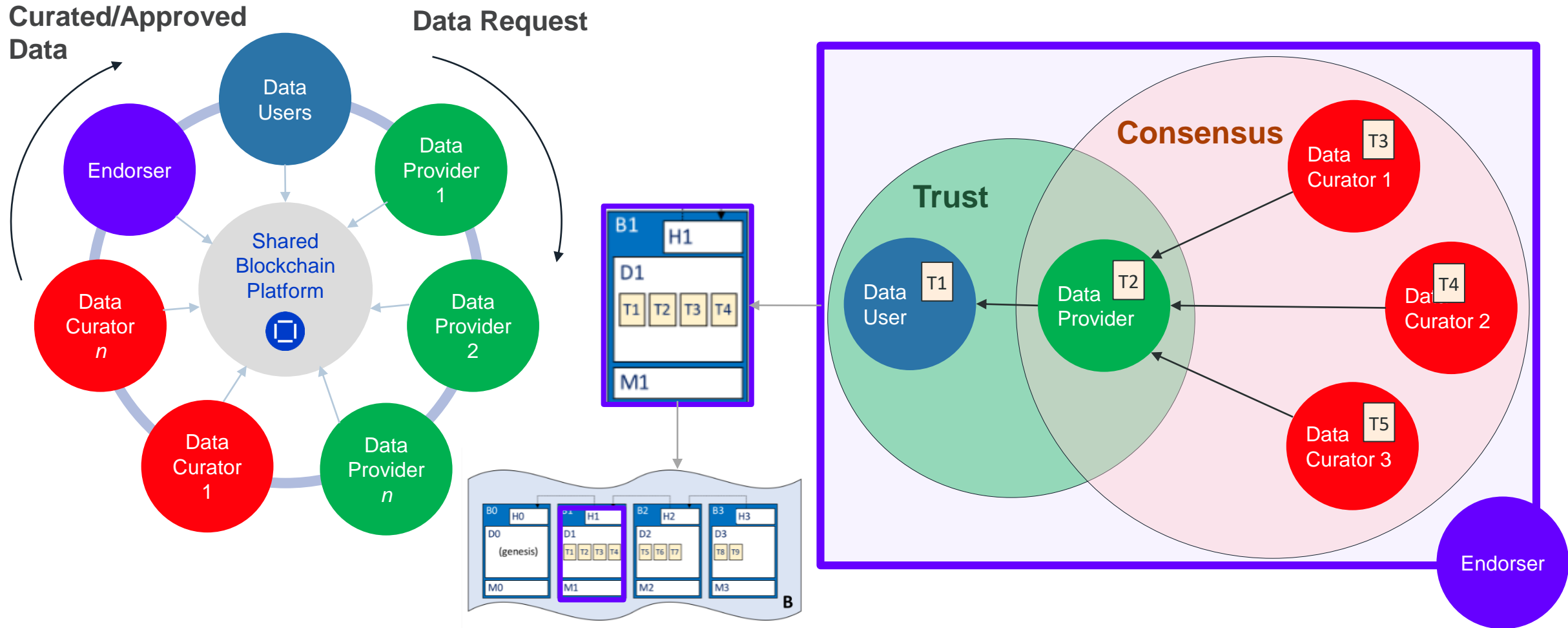


The Anatomy of a Blockchain



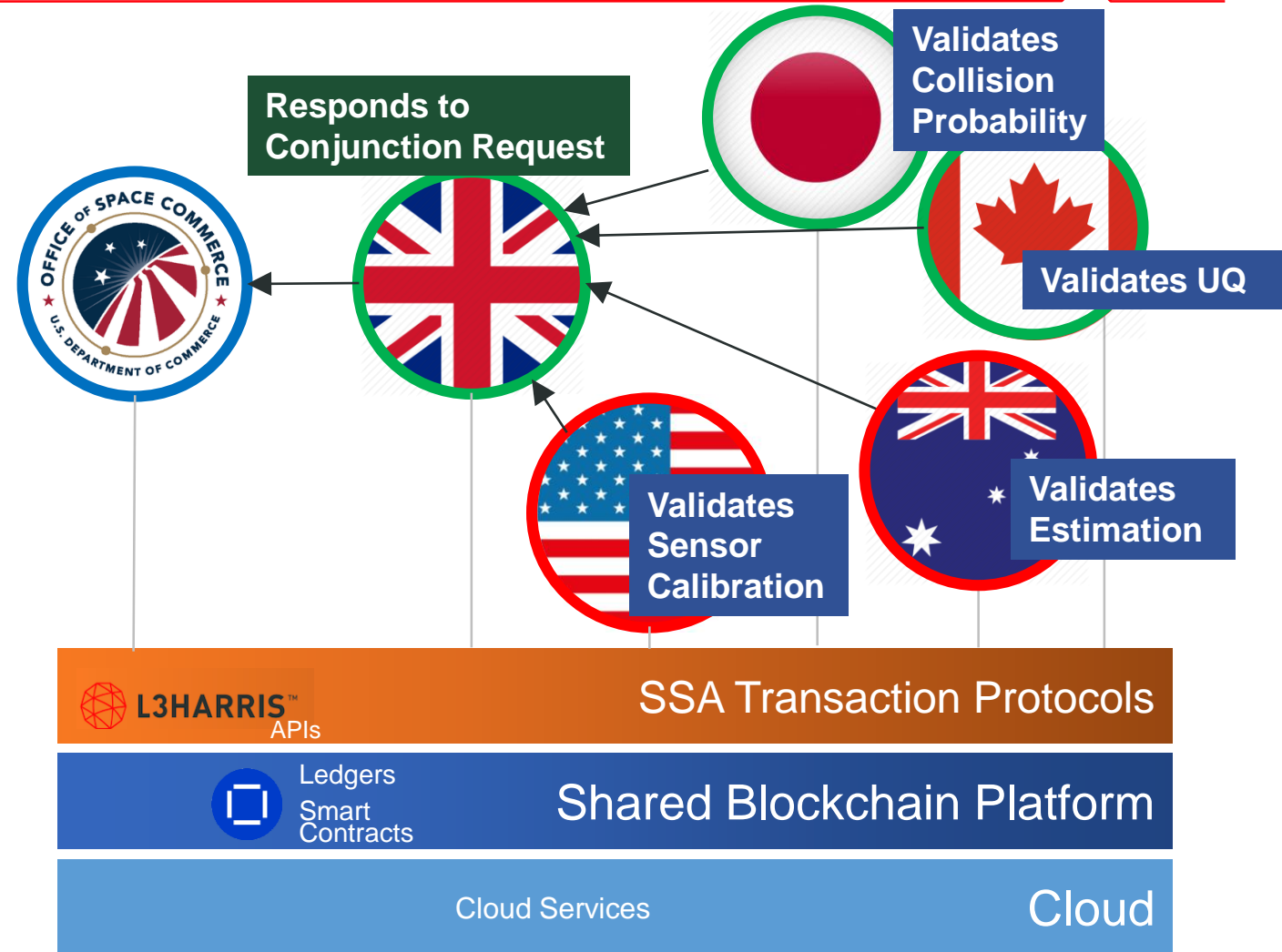
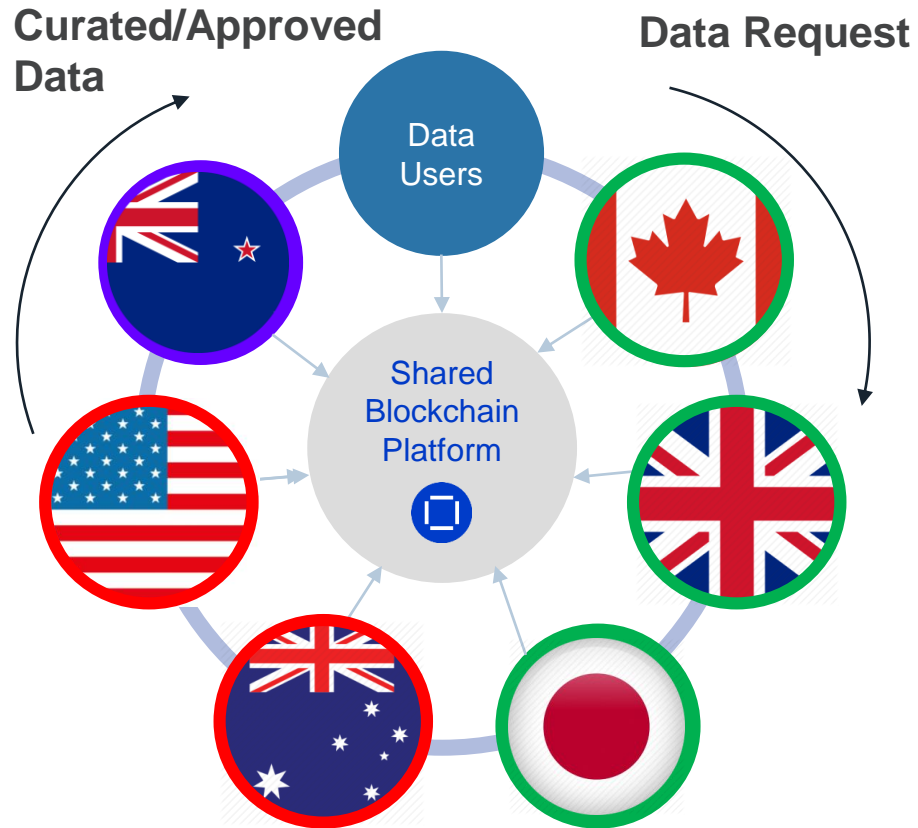
Blockchain Enables Organization, Attribution, Provenance, and Immutability

Innovation – Using Deconstructed Blockchain Technology for Establishing Trust in Data



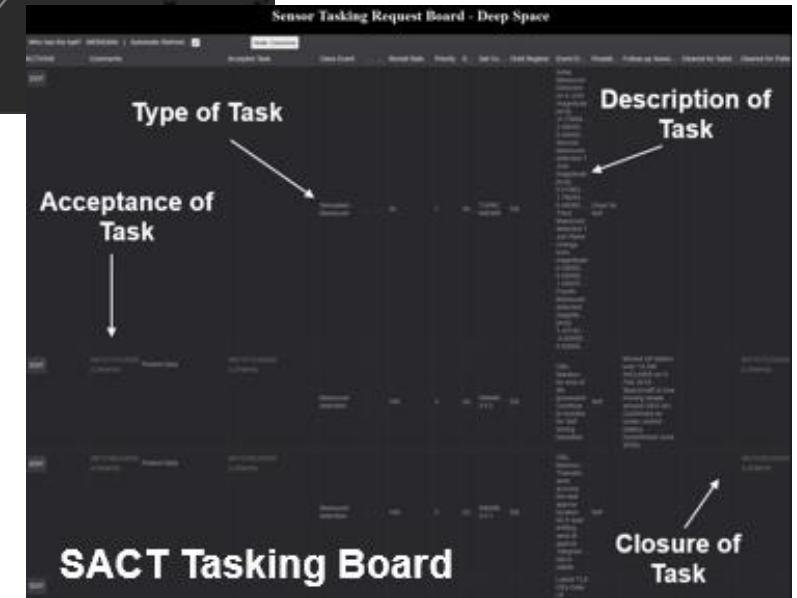
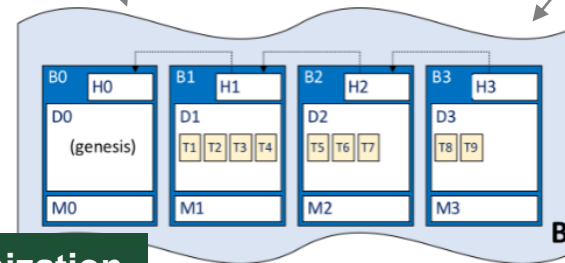
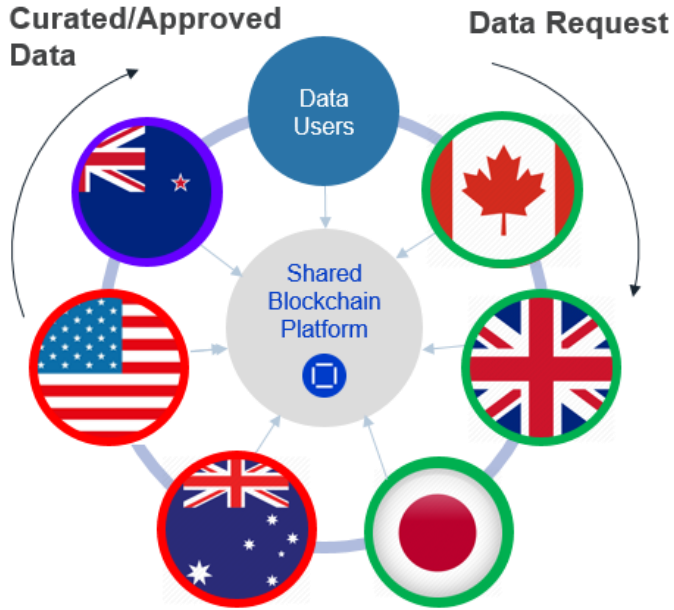
The Request, Provision, and Curation of a SDA Data Request is Logged on a Blockchain

Using Deconstructed Blockchain Technology to Achieve Consensus



Multiple Decentralized Commercial/Allied SDA Nodes Work Together to Build Trust in Data

Progress – Utilization in Sprint Advanced Concepts Training (SACT) Exercise



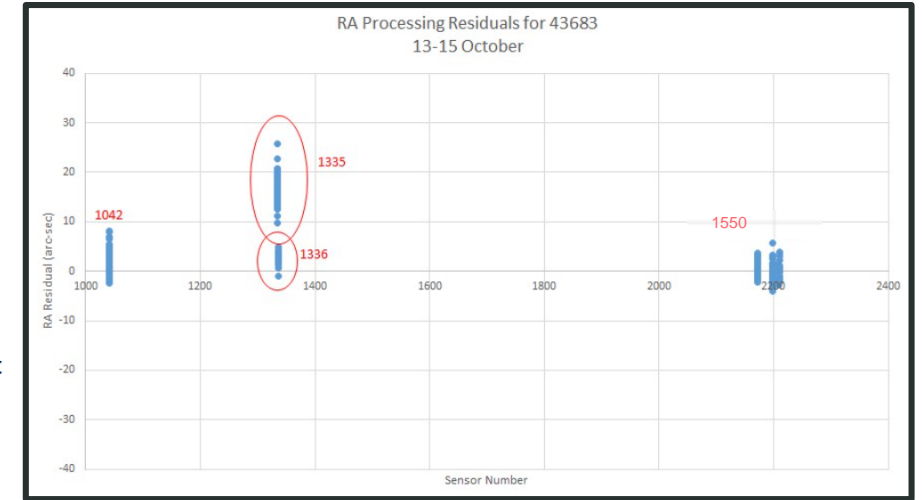
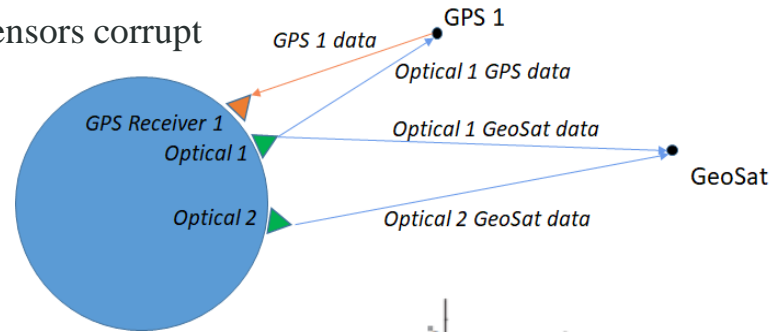
A Blockchain Prototype for Decentralized SSA Was Successfully Demonstrated at the SACT 20-2

2-Tier Data Validation and Consensus on Blockchain



Tier 1: Validation using Multi-state Filter Implementation

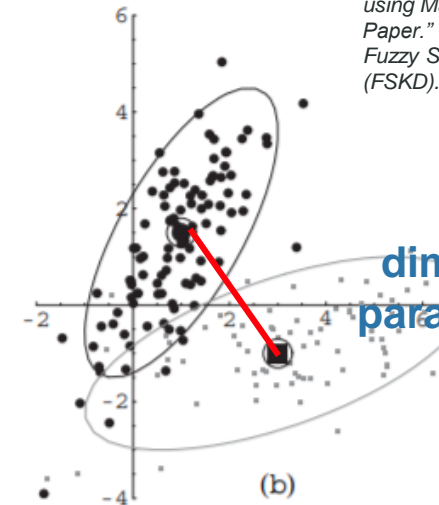
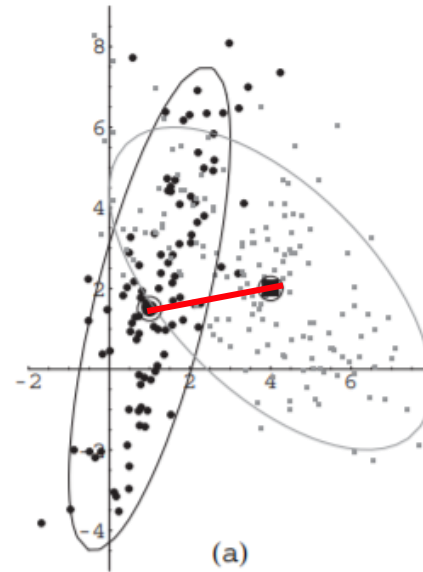
1. Given GeoSat data from two disparate sensors
2. One or the other is calibrated
3. Consistency metrics not met
 - Consensus reached that one or both sensors corrupt
4. Hypotheses
 - Station Coordinates Incorrect
 - Aberration Not Accounted For
 - Reference Frames
 - Timing Biases
5. Run each data provider separately



Tier 2: Consensus using Independent PDFs

TABLE 2
Analytic Expressions of Probabilistic Distances between Two Gaussian Densities

Distance Type	Analytic Expression
Chernoff distance	$J_C(p_1, p_2) = \frac{1}{2} \alpha_1 \alpha_2 (\mu_1 - \mu_2)^T [\alpha_1 \Sigma_1 + \alpha_2 \Sigma_2]^{-1} (\mu_1 - \mu_2) + \frac{1}{2} \log \frac{ \alpha_1 \Sigma_1 + \alpha_2 \Sigma_2 }{ \Sigma_1 ^{\alpha_1} \Sigma_2 ^{\alpha_2}}$
Bhattacharyya distance	$J_B(p_1, p_2) = \frac{1}{8} (\mu_1 - \mu_2)^T [\frac{1}{2} (\Sigma_1 + \Sigma_2)]^{-1} (\mu_1 - \mu_2) + \frac{1}{2} \log \frac{ \frac{1}{2} (\Sigma_1 + \Sigma_2) }{ \Sigma_1 ^{1/2} \Sigma_2 ^{1/2}}$
KL divergence	$J_R(p_1 p_2) = \frac{1}{2} (\mu_1 - \mu_2)^T \Sigma_2^{-1} (\mu_1 - \mu_2) + \frac{1}{2} \log \frac{ \Sigma_2 }{ \Sigma_1 } + \frac{1}{2} \text{tr}[\Sigma_1 \Sigma_2^{-1} - \mathbf{I}_d]$
Symmetric KL divergence	$J_D(p_1, p_2) = \frac{1}{2} (\mu_1 - \mu_2)^T (\Sigma_1^{-1} + \Sigma_2^{-1}) (\mu_1 - \mu_2) + \frac{1}{2} \text{tr}[\Sigma_1^{-1} \Sigma_2 + \Sigma_2^{-1} \Sigma_1 - 2\mathbf{I}_d]$
Patrick-Fisher distance	$J_P(p_1, p_2) = [(2\pi)^d 2\Sigma_1]^{-1/2} + [(2\pi)^d 2\Sigma_2]^{-1/2} - 2[(2\pi)^d \Sigma_1 + \Sigma_2]^{-1/2} \exp\{-\frac{1}{2} (\mu_1 - \mu_2)^T (\Sigma_1 + \Sigma_2)^{-1} (\mu_1 - \mu_2)\}$
Mahalanobis distance	$J_M(p_1, p_2) = (\mu_1 - \mu_2)^T \Sigma^{-1} (\mu_1 - \mu_2)$



Rabal, H. "Decision and classification problems using Mahalanobis statistical distance Conference Paper." 2011 Eighth International Conference on Fuzzy Systems and Knowledge Discovery (FSKD).

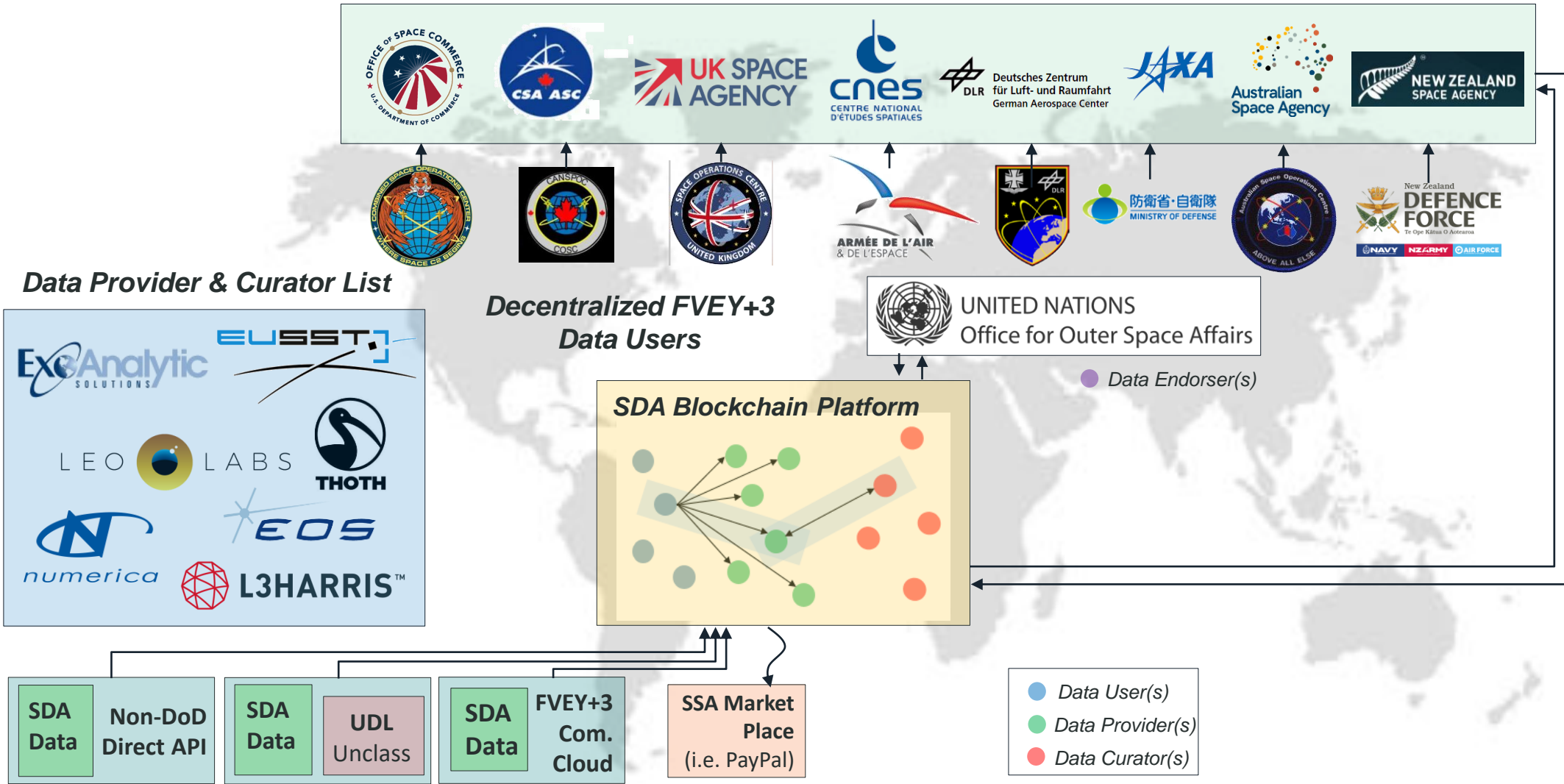
Simulation of two examples of two-dimensional spaces of parameters with normal distributions

1. Zhou et al. "From Sample Similarity to Ensemble Similarity: Probabilistic Distance Measures in Reproducing Kernel Hilbert Space" IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 28, NO. 6, JUNE 2006

Validate Calibration + Validate Estimation + Uncertainty Quantification → Consensus

What Does Success Look Like?

A Worldwide Framework to Establish Trust in SDA Data



The Whole is Greater than the Sum of its Parts – A Worldwide SDA Construct Requires Strong Independent Nodes

How Can We Manage an SSA Data Exchange Ledger to Establish Trust?



SSA Data Exchange Ledger

Regulatory

- Provision & Curation certificates
- Multilateral Trade Agreements
- Ensures daily member compliance

Member Engagement

- Initial outreach
- Communications
- Agreements and consortium management
- Set space sustainability policies

IT/Security

- Establish IT protocols
- Ensure double blind concept
- Manage interface with high side

Operations

- Manages technology platform
- Manage Data and monetary transactions

Forensics

- Investigates incidents (near misses, collisions)
- Determine root cause
- Record lessons learned to avoid future issues

Execution of a Deconstructed Blockchain for SSA Requires Several Areas of Support

Regulations to Operate SSA Data Exchange Ledger



Regulate

			 Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center			



ICAO works with the Convention's 193 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector.

Do we Need to Stand up an ICAO type Organization for STCM?

Nodes Left Free to Each Regulate Themselves, Tend to Produce Spontaneous Order

