A FEDERATED SYSTEM FOR MULTI-SENSOR GEOINFORMATION DATA

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ABSTRACT

Federated systems are a key commodity of modern mission management, e.g. for the support of tactical operations with the provision of relevant imaging information. Such can be made available by the already military-proven and operationally deployed software solution Jagwire™. Jagwire highlights the capabilities of a federated enterprise system for the ingestion, compression, storage, cataloguing, and dissemination of geospatial information. Compliant with industry standards (Open Geospatial Consortium, OGC) and robust well-defined Application Programming Interfaces (APIs), Jagwire supports interoperability and integration with a wide variety of geospatial applications, including ENVI® and ArcGIS®. With focus on ad-hoc creation of advanced information products from both real-time and archived geospatial data, collected from a broad range of orbital, unmanned and fixed-wing sources.

Index Terms— federated systems, interoperability, data discovery, visualization, video, imagery, geospatial intelligence

1. INTRODUCTION

An essential aspect of modern mission management is the connectivity between the stakeholders, including the sharing of relevant reconnaissance imagery, which is critical to establish comprehensive situational awareness. For this purpose, information from Imagery Intelligence (IMINT) must be collected, evaluated and – together with other Geospatial Intelligence (GEOINT) information – be made available to the operational command with minimal delay.

Compatibility issues, however, often prevent access to key data sources. At the same time, it is not always easy to filter and recognize the relevant data in a timely manner from the growing flood of information.

To directly assist military forces in tackling current and future tactical challenges, L3HARRIS has developed Jagwire. Operationally deployed and mission proven, Jagwire transforms the way geospatial data is acquired, secured, discovered and visualized. Jagwire supports *any* end-user – through its web-based interface, *anywhere* – from data centres to the tactical edge, *any data* – multiple modalities including Full Motion Video (FMV), imagery, Moving Target Indication (MTI), Light Detection And Ranging (LiDAR) and more, and at *any time* – whether it is real-time or on demand.

Jagwire was designed around seven tenets:

- Deploy next to the sensor and data sources
- Leave the data where it was collected
- Move the data only when it is required
- Move the data only to where it is required
- Minimize the amount of data sent
- Send the answer and not the data when possible
- Anything within the enterprise can be a sensor and/or a consumer.

At the foundation of these tenets is the support of data-federation by Jagwire. Federation for Jagwire was built with the purpose to support the complicated nature of both data collection and data discovery process, as well as the operational networks and infrastructure. With a desire to provide enhanced situational awareness, L3HARRIS recognized the need to provide enterprise wide accessibility to data holdings of operational systems. The inherent challenge is accomplishing this with globally deployed systems which contain thousands of hours of video and millions of images. It started on the premise that federation does not mean data replication – replicating data to all systems is simply impractical and would not solve the problem but rather create more of them. In taking that approach, Jagwire was designed to "talk" to other systems through the federated network to provide instant awareness and visibility to all data (both live and archive) and only move it when required.

This approach in Jagwire allows users to quickly find and use data anywhere in the enterprise. Additionally, the integrated analytic platform, lets users access advanced analytical functionalities, supporting them to rapidly find the insights that are needed to make informed decisions.

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2. OVERVIEW

Jagwire has consistently delivered insights for the defence and intelligence community through state-of-the-art video processing, data analytics, and powerful automated geospatial data federation capability. Figure 1 shows all components required for such a federated software system supporting multi-sensor geoinformation data.

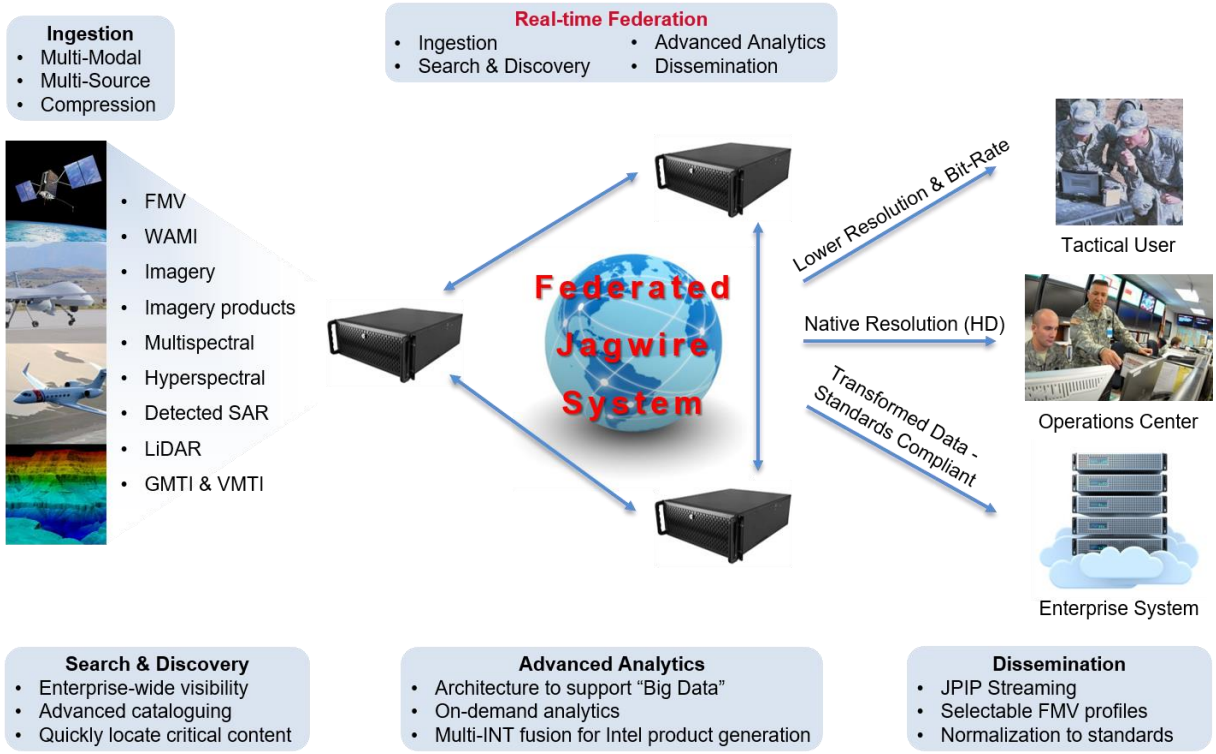

Fig. 1. Requirements for a federated system for multi-sensor geoinformation data.

L3HARRIS developed the Jagwire architecture for managing multi-modal and multi-INT sources as well as the associated metadata. This architecture provides the answer to the "what", as well as the "where" and "when". To that regard Jagwire delivers a system that is:

- *Instant, intuitive and with unified access.*
  Quickly provide tactical operators the information needed from large images and videos. Digitally stream FMV, Wide Area Motion Imagery (WAMI), LiDAR Digital Elevation Models (DEMs) and satellite imagery with near real-time delivery and visibility to active collections.
- *Enterprise-wide visible to assets for greater reach of vital information.*
  Manage unrelated types of content at an enterprise level with unified and centralized access to all imagery and video collections. As well as the ability to search for content based on location, time and other keywords – with full archived data support. Federation provides enterprise-wide visibility, delivering access to a larger data set of information.
- *High performant on low-bandwidth and high latency networks.*
  Ensure tactical operators in austere environments – where networks frequently fail – get the critical intelligence needed to complete their objectives with the ability to disseminate to handheld devices using the Jagwire Media Engine and JPEG 2000 Interactive Protocol (JPIP) streaming.
- *Standards-based and interoperable.*
  Compliance with adopted industry and defence-specific standards including Open Geospatial Consortium (OGC), North Atlantic Treaty Organization (NATO), Motion Imagery Standards Board (MISB) and National Imagery Transmission Format (NITF). This ensures interoperability, enabling Jagwire to consume and disseminate data to other upstream and downstream systems. Support OGC interfaces include Web Coverage Service (WCS), Web Mapping Service (WMS), and Web Feature Service (WFS). Those standards allow Jagwire to capture and process a broad range of data sources including Defence and Intelligence assets as well as video from first responders, commercial and broadcast sources.
- *Flexible and scalable.*
  Open interfaces enable integration into existing systems to help complement or augment operational capabilities – reducing costs associated with migrations, training and deployment. The distributed architecture of Jagwire addresses the growing adoption of cloud computing

environments, eliminating costs associated with moving and managing data.

3. SPECIFICATIONS OF A FEDERATED SYSTEM

With the rapid adoption and development of new systems as well as new data types, the need for federation and interoperability is now more critical than ever. Jagwire was designed to federate and to provide unfiltered access to all the data holdings in the enterprise. It achieves this through the adoption of industry and community standards as well as access to fully documented APIs. This approach allows end-users in the Jagwire ecosystem to discover data wherever it resides, and in almost any external system, such as C2/C4ISR systems (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance) as well as widely deployed systems developed by ESRI, BAE Systems, and the L3HARRIS developed hC2™ and Individual Solider System (ISS). Furthermore, with no need for client-side software installs, as Jagwire is accessed via a web browser, the barrier to entry is removed as end-users only need a standard web browser and access to their specific system.

3.1. Data management

Imagery has become an important part of mission critical operations. Whether an organization is using satellite imagery, Unmanned Aerial Vehicle (UAV) and aerial imagery, or hand-held collected data from field operations, managing this data in a way that it is easy to discover is a game changer. Data collected and made actionable across systems, across networks, and across geographies can enable teams to better communicate, operate, and react to a variety of changing environments.

On-demand and easy-to-find data is critical for operations, it enables that unfolding events can be influenced and unexpected challenges be met. Hardened data management protocols and the ability to process large volumes and varieties of data, enable Jagwire to quickly provide actionable intelligence to teams in the field.

Tab. 1. Jagwire format support for data ingestion and transformation.

Ingestion	

Analog Video
• EIA-608 Closed Caption
• NTSC or PAL/M Composite and S-Video
Digital Compressed Video
• H.264 Video (ISO/IEC 14496-10)
• MPEG2 Transport Stream (TS) over UDP/IP multicast or unicast (ISO/IEC 13818-1)
• MPEG2 Video (ISO/IEC 13818-2)
• SD 480i/p
• HD 720p, 1080p
Codec
• H.264 / MPEG4 Part 2
• MPEG1
• MPEG2
Video Metadata
• Transports:
  • MPEG2-TS SMPTE RP217-2001 Asynchronous & RP 0604 Synchronous KLV
  • Serial (RS-232, RS-422)
  • UDP/TCP multicast or unicast separate or multiplexed in MPEG2-TS
• Formats:
  • Exploitation Support Data
  • SMPTE 336M Key Length Value (KLV) including MISB EG 0601.2 & EG 0104.5
  • Common Data Format (CDF)
  • Viewable ESD / Warrior CDRL A032
  • KLV FireScout & Rover
	Imagery
	• Imagery types:
	  • Detected Synthetic Aperture Radar (SAR)
	  • Hyperspectral Cubes (HSI)
	  • LiDAR point clouds
	  • LiDAR product zip files / US Army Geospatial Center (AGC): Digital Elevation Models (DEMs) and Merge / Intensity data
	  • Multispectral (MSI)
	  • Vector
	• File formats:
	  • GEOTIFF
	  • JPEG
	  • JPEG 2000
	  • LAS, NITF wrapped LAS
	  • Shapefile
	  • STANAG 4545 (NITF 2.0 / 2.1)
	Chat
	• XMPP or Internet Relay Chat (IRC) rooms, associated with an input video/metadata feed
	MTI
	• Ground Moving Target Indicator (GMTI) (STANAG 4607)
	• Visual Moving Target Indicator (VMTI) (MISB 0903)

Image scientists, image analysts, and war fighters all need timely information, and to do their jobs well they need proven technologies that let them discover crucial data sets and prepare it for analysis. Being able to extract features, and to better analyse terrain and objects, is crucial. Jagwire is proven to transform and deliver data for obtaining strategic and tactical advantage. Table 1 shows the extensive support for data ingestion and transformation which is foundational in establishing utility and effectiveness of data management systems.

Video provides a unique challenge for data management systems as they can be ingested as live streams, which means new data is created over time and space in real-time. Jagwire handles these challenges in a few different ways. The first is a robust centralized web-based management tool for configuring all incoming live captures. This tool is coupled with an interface designed to show real-time status of all

captures being collected. By this combination Jagwire provides a powerful solution to see the complete operational picture.
Additional, but essential characteristics include:

- User communities are enabled to enrich content through the creation of annotations, which are shared across the system.
- Chat messages can be captured and synced to individual frames of video.
- Support of non-traditional data types tied to spatial products
- (PowerPoints with flight details, reports generated for support or maintenance, etc.).
- Embedment of advanced analytics.

3.2 Data discovery and visualization

Discovery and visualization are core to L3HARRIS and finding the critical data that you need and then visualizing that data to better operate and make informed decisions is a paramount feature in Jagwire. Access to data across the value chain of a scientist, analysts, to the tip of the spear is achieved with high precision and advanced visualization techniques. Available on mobile and radios, over low bandwidth networks, Jagwire delivers critical intelligence. Teams and field operatives can acquire real time imagery and analytics at the tactical edge via remote access and data connections.

Jagwire remains a best in class tool for visualizing multi-modal data. With the advancement of the native tools and investment in new and emerging technologies such as HTML5, DASH (Dynamic Adaptive Streaming over HTTP), High Efficiency Video Coding (H.265), and more, Jagwire provides a unique experience and feature set for consumers of data. Functionality like dynamic and controllable overlays, video zoom, colour correction, transcoding on the fly, integrated annotator, and more are available out of the box and work for both high-bandwidth consumers as well as users with limited bandwidth:

- Auto-detection and configuration of parallel live feeds for near real-time delivery.
- Access to FMV metadata.
- Map-based visualization of FMV sensor, target and flight path to ensure the mission captured the critical intelligence needed.
- Overlay of Video Moving Target Indicator (VMTI) on FMV.
- Add context and enhance understanding with annotations and associated chat text.
- Out of the box support for almost any scenario (low- / high-bandwidth delivery):
  On-the-fly transforming data types, transcoding video sources, routing to any destination using any number of standard protocols.

For other modalities, Jagwire provides robust options for visualization. This includes a feature rich JPEG 2000 Interactive Protocol (JPIP) client for imagery as well as a web-based 3D tool for LiDAR (see Figure 2).

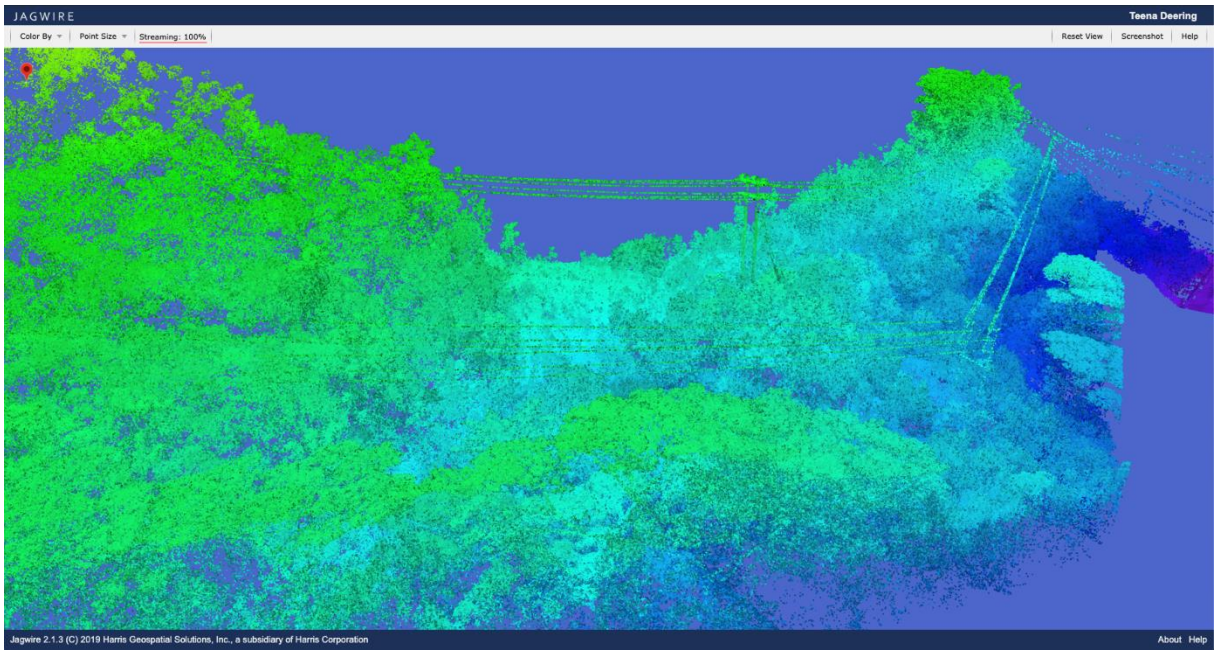

Fig. 2. Interactive 3D visualization tool showing a LiDAR point cloud.

For data discovery, Jagwire has earned a reputation as a top tier solution. The user experience allows searching for data based on geospatial information, time, platform, mission ID, and other metadata and keywords. The geospatial search request can be entered in coordinate systems including World Geodetic System 1984 (WGS84) Latitude/Longitude and

Military Grid Reference System (MGRS) for areas of interest or drawn on customer specific reference maps using a box, radius, or a point search. The search can be performed over the entire enterprise or any specific Jagwire node using one single interface. In addition, Jagwire provides the user with the ability to navigate through the archived flight path using temporal scrubbers to pick the location within the mission and the duration.

3.3 Data dissemination

Jagwire is a browser-enabled solution that delivers an integrated platform for the processing, storing, discovery, and exploitation of geospatial data. Jagwire can disseminate FMV, satellite and aerial imagery, Synthetic Aperture Radar (SAR), LiDAR, and even mission chat sessions to ensure that workflows and systems are ready at the right time to the people who need it most. Users in the field or in an operation centre can quickly locate critical intelligence with advanced discovery and filtering capabilities.

Conserving enterprise infrastructure, whether it is disk space or bandwidth, keeps a system up and running, and costs under control. The Jagwire architecture is designed to get the most out of existing infrastructure. Therefore, Jagwire was optimized to working in almost every network environment, from high speed to low-bandwidth networks coupled with high latency.

Specifically, this includes low-bandwidth radio and tactical communications, satellite communications, as well as ad-hoc mesh and Long-Term Evolution (LTE) networks. Jagwire has no external dependencies, so running in environments where internet access is unavailable (e.g. private or secure networks) poses no problems for the system to operate. JPIP streaming enables delivery of imagery without loss of resolution, and FMV can be transcoded on-the-fly at lower bit rates. Table 2 lists the standards and protocols used to ensure effective data dissemination.

Tab. 2. Standards and protocols used within Jagwire to ensure effective data dissemination.

Dissemination	
Video Multiple outputs at varying bit rates and resolutions available per input: • H.264 Video (ISO/IEC 14496-10) • KLV as EG 0104.5 or EG 0601.2 • KLV multiplexed as SMPTE RP217- 2001 Asynchronous & RP 0604 Synchronous KLV • MISP/STANAG 4609 compliant products • MPEG2 Transport Stream (TS, ISO/IEC 13818-1) • MPEG2-TS via HTTPS • MPEG2 Video (ISO/IEC 13818-2) • RTSP streams • RTP interleaved over RTSP • RTP over UDP/IP • RTSP/RTP interleaved over HTTP • UDP/TCP multicast or unicast • VMTI (MISB 0903) **Other Available Video Outputs** • MPEG1 (MS Office support) • MPEG4/QuickTime	**Codec** • H.264 / MPEG4 Part 2 • MPEG2 **Video Metadata** • High-res profiles: Supports ingested KLV metadata or normalized to KLV LDS • Low-res profiles: KLV LDS 0601 **Imagery** • JPIP streaming: • JPEG 2000 • Point cloud streaming • Download ingested assets (chipped or full) **MTI** • Ground Moving Target Indicator (GMTI) (STANAG 4607) • Visual Moving Target Indicator (VMTI) (MISB 0903) **Web Interfaces** • HTTP REST • OGC (WCS, WFS, WMS)

3.4 Data security

Confidence in security and data control is at the heart of Jagwire. Based on the most secure digital environmental architectures, Jagwire is deeply rooted in data security.

3.4.1 Encryption

Jagwire implements third party encryption libraries to provide secure communications for Secure Shell (SSH), SSH File Transfer Protocol (SFTP), Hypertext Transfer Protocol Secure (HTTPS), and Simple Object Access Protocol (SOAP) web services. The software does not add any additional pre-processing methods to the data prior to encryption and does not perform any post-processing of the data after it has been encrypted.

- *Open source Secure Sockets Layer (OpenSSL):*
  Utilizes SSL and Transport Layer Security (TLS) protocols. Provides secure network communications when connecting to HTTPS, JPEG 2000 Interactive Protocol Secure (JPIPS), or File Transfer Protocol (FTP).
- *Oracle Java Platform, Standard Edition Development Kit 7 (JDKTM):*
  Provides Simple Object Access Protocol (SOAP) message level security, used by Oracle's Metro JAX-WS SOAP web services framework.
- *Transport level encryption is used to protect SSH, SFTP, and HTTPS communications:*
  All three transfer protocols make use of OpenSSL to perform the actual encryption. Each application that implements one of these transports has its own configuration files which are protected using operating system level file permissions that specify the details of

the algorithm used. The system also has Tripwire® and Advanced Intrusion Detection Environment (AIDE) available to be able to detect and notify when files are changed. For HTTPS and SFTP, a Privacy-Enhanced Mail (PEM) formatted private key and x509 certificates are installed on the system and protected using the same file level protection described above.

- *Message level encryption is used within SOAP based web services:*
  The software uses Oracle's Metro JAX-WS SOAP web services implementation to handle all web services specifics including the message level protection. Metro makes use of the built-in encryption capabilities provided by Oracle JDKTM. The configuration of the protection is stored in files and protected using the same operating system level protections described above. The private key and certificate along with the TrustChain are stored with Java keystone files.

In addition to the third-party encryption components, Jagwire provides the ability to receive encrypted instant messaging chat through Extensible Messaging and Presence Protocol (XMPP) and Internet Relay Chat (IRC) clients. The XMPP client utilizes Simple Authentication and Security Layer (SASL), TLS, and SSL. The IRC client can be configured to use SSL.

3.4.2 Security and information assurance

L3HARRIS recognizes the criticality of maintaining the security posture of operational systems and the constant need to protect access to data and the system. Cyber threats continue to grow in sophistication and Jagwire has made Security and Information Assurance one of the highest priorities for system sustainment and support. Some key data points as it relates to this topic:

- Jagwire is certified and accredited to be deployed on some of the most highly classified and operational networks, for example the Joint Worldwide Intelligence Communications System (JWICS).
- Jagwire is configured per US Defence Information Systems Agency (DISA) and the US National Security Agency's (NSA) technical guidance.
- Jagwire supports standard US Department of Defence (DoD) Public Key Infrastructure (PKI) server and user certificates.
- Jagwire constantly monitors for vulnerabilities and is Information Assurance Vulnerability Alert (IAVA) conforming.

3.5 Data analytics

The purpose-built architecture of Jagwire is designed to support large volumes, variety and velocity of data – "Big Earth Data" from traditional and non-traditional sources (Big Earth Data refers to big data associated with Earth observation).

3.5.1 Integrated advanced analytics

Directly from the browser interface of Jagwire, end-users can rapidly transform Big Earth Data into information using scientifically proven analytics of ENVI. With access to the most up-to-date data in near real-time, multi-INT fusion for Intelligence and Map product generation enables more informed decisions based upon all the information available.

Analysing areas of unrest, deciphering topography, or responding to growing threats, stakeholders need to quickly analyse imagery and unstructured data types to quickly develop strategic intelligence and deliver it to those who need it, when and where they need it. As Jagwire is combined with a cloud-deployed version of ENVI, the analytics are moved to where the data resides – making it possible to quickly create on-the-fly geospatial products with thin and mobile clients. Some examples of supported image analytics capabilities include:

- *Anomaly detection:* Search an image for statistical and spectral distinctions from the background landscape.
- *Pan sharpening:* Automatically merge a low-resolution colour, multispectral, or hyperspectral image with a high-resolution panchromatic image.
- *Change detection:* Look for areas of change by comparing two images from different dates using band ratio or feature index techniques.
- *Classification:* Classify terrain automatically or with user defined specifications.
- *Feature extraction:* Find objects of interest using parameters based on spatial, spectral, and textural characteristics.
- *Spectral analysis and target detection:* Allows for using pixel responses at different wavelengths to obtain information about the materials within each pixel.

In addition, Jagwire has harnessed the advanced analytics to multiple modalities, including FMV, LiDAR, and SAR. Here, radar reconnaissance is of special relevance. Satellite-based radar reconnaissance systems such as SAR-LUPE use SAR technology to provide high-resolution images of the Earth's surface by day and night, regardless of the current light and weather conditions.

With ENVI SARscape analytics, SAR data from all spaceborne and selected aircraft-based sensors can be easily processed and analysed to generate advanced information products. The automated workflows include Time Series Analysis, Moving Target Detection (MTD), and Ship Detection combined with Automatic Identification System (AIS) traffic information. It also supports the processing of data to create high-resolution DEMs, as well as thematic maps, e.g. Coherence Change Detection (CCD) and Terrain Deformation maps.

Or, ENVI and ENVI SARscape can act as completely interoperable, stand-alone solutions within existing products and infrastructure. With native access to ENVI analytics, users can generate customized workflows on demand using the more than 200 different tasks that are already available out of the box. Integrated in Jagwire, customers can easily

apply homegrown analytics across their enterprise allowing for wide access and adoption of valuable tools.

3.5.2 Analytics with machine learning

While military tactics are being continuously improved, there also needs to be an improvement in the way geospatial information is analysed. The Big Earth Data collected by satellites, airborne and ground systems, needs to be exploited in the operational area in an organized manner to make the information insightful. Imagery, terrain information, and data from multiple sensors can be used to create situational awareness by applying deep learning, statistical analysis, and probabilistic algorithms to such data.

L3HARRIS has developed a suite of state-of-the-art, deep learning-based tools called Mega™ that are designed specifically to work with imagery to solve geospatial problems.

Mega™ excels in in automated target detection, land cover classification mapping, and automated scene state detection. Highly tuned processes are employed that rely on high-performance computing to train a Convolutional Neural Network (CNN) which in turn can help identify and extract objects of interest or discover specific conditions across vast quantities of images. Our deep learning technologies obtain near ceiling performance on Pan, RGB, MSI, HSI, SAR, LiDAR, and derived point cloud data sets.

4. CONCLUSIONS AND OUTLOOK

Jagwire highlights the possibilities of a federated enterprise system for the ingestion, compression, storage, cataloguing, and dissemination of geospatial information and data. To support tactical operators in austere environments, the Jagwire architecture is optimized for low-bandwidth and high-latency networks, including dissemination to thin clients and mobile devices. Furthermore, it is designed to support "Big Earth Data" and enables the ad-hoc creation of advanced information products from both real-time and archived geospatial data.

However, near-real-time geospatial data must be analysed in a short time so that time-critical decision support can be provided. Particularly the integrated data mining algorithms for advanced radar reconnaissance and deep learning-based target detection involve high computational complexity. Unfortunately, the optimization of those algorithms will not be sufficient to obtain the required and expected performance.

Therefore, High-Performance Computing (HPC) techniques, which are characterized by parallel processing capabilities such as multiple-core Central Processing Units (CPUs), Graphics Processing Units (GPUs), cluster, or cloud computing are essential to overcome the latency of advanced analytics. The implementation of such computing devices should be considered when configuring the optimal hardware for a Jagwire federation. On the software side, L3HARRIS solutions for cluster and cloud computing are already available to create a scalable system.

Jagwire continues to advance and adapt to support the evolving mission and technology landscape. Innovation will continue to be a driving factor on Jagwire. Future forward leaning innovations include the exploration into the following areas:

- *Collaboration:* User to User and System to User.
- *Suggestive and predictive services:* Harvesting information not only from data, but also involving user behaviours and interactions across the enterprise.
- *User and system relationships:* Mining data about users (i.e. the data collected, utilization and consumption) to create new opportunities for features, interactions and generation of derived products.
- *Advanced visualization:* Multi-INT displays and aggregation, rich product interaction and consumption.
- *Advanced search:* Social and quality metrics.

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