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EXECUTIVE OVERVIEW

Unmanned vehicle systems (UVSs) are becoming increasingly prevalent; their use has increased exponentially over the last decade. On the land, in the sea, and in the air, UVSs are used for a broad range of tasks including security, hazardous waste clean up, monitoring of agricultural crops, law enforcement, as well as military operations. New uses for these systems are being identified every day.

UVS systems use software for functions such as communications and data links, vehicle control, sensor control, and data management. Communication and data links standardization has been driven by spectrum requirements, and working groups exist to ensure commonality. Vehicle control software is rapidly maturing and, in the case of unmanned air vehicles, will be driven by the need to operate in controlled airspace. It is widely recognized that the movement of data is key and that open architectures and standards are needed. The rapid growth and urgent need for UVSs has resulted, however, in software for sensor control and data management being largely developed with standardization and open architectures in mind, but independent of unifying standards.

Oracle products not only comply with standards, Oracle actively supports and leads numerous industry standards organizations. The use of Oracle commercial off-the-shelf (COTS) software leverages this long-standing and ongoing commercial investment and can accelerate delivery of capability, while reducing cost and risk. Oracle offers a variety of products that can be used by unmanned systems, including a robust, lightweight database specifically optimized for in-memory use and an enterprise service bus with a business process rules engine. It also provides extremely robust system security for those UVSs with sensitive missions.

This white paper describes these products, explains how they can be used and highlights the benefits of using COTS software that supports open architectures and commercial standards.
UVS SOFTWARE CHALLENGES

UVSs come in a wide variety of configurations. Some are small and tactical, while others are large and strategic. Vehicles travel on land, in the sea or in the air, while using many types of sensors and communication patterns.

This diversity has naturally led to a great deal of one-of-a-kind software. However, underlying this variety is a great deal of commonality. Therein lies a large opportunity to reduce cost, complexity and risk, by standardizing on common software architectures and products. Furthermore, these architectures can now be implemented using standards compliant COTS software to provide stable, mature solutions at lower cost and risk.

Not any COTS architecture, however, can meet the unique UVS requirements. To be successful it must address challenges in the following areas:

- **Footprint**: Onboard systems must occupy a small footprint while providing reliable data storage, and a standards-based platform of flexible and modular components.

- **End-to-end turnaround time**: The success of the mission depends on how fast data can be captured, transmitted and then integrated, analyzed and converted into action.
• **Flexibility and Configurability**: UVS capabilities and missions are constantly changing. The architecture must be rapidly and easily reconfigurable and extensible.

• **Security**: In certain applications security is critical. Onboard security must prevent unauthorized access in case the vehicle is lost. Ground stations must provide comprehensive security for data sharing between multiple organizations: ensuring appropriate use of sensitive and classified information.

• **Reliability and Availability**: Onboard systems operate remotely or autonomously, in conditions that are sometimes hazardous or inaccessible. Ground stations’ operational models vary, but all require high levels of availability during missions.

• **Cost reduction**: The software platform should help keep down costs by optimizing productivity and automation, as well as by enabling the use of lower cost components - today and in the future.
UVS SOFTWARE ARCHITECTURE

The main components of a UVS architecture are shown in Figure 2. The following sections describe how this architecture, and Oracle technology, support the key challenges for UVSs.

Unmanned vehicles need to store various metadata and buffer collected data before transferring it to the ground station. Often, however, there is a very limited resource footprint onboard. Oracle provides databases that can accommodate this constraint. Berkeley Database, in particular, is a high performance, open-source, database for mission-critical embedded systems that occupies a tiny footprint (<1MB). It runs in-memory, is high performing, and works with real-time operating systems (RTOSes). Oracle Berkeley DB is used by all versions of Linux, BSD Unix, OpenLDAP, OpenOffice and hundreds of other open source software packages. Of particular note, it is embedded as the data store in the Army's Command Post of the Future.
End-to-End turnaround time

The architecture must minimize not only the time it takes to collect and transfer data, but also the time it takes to convert that data to action.

Data collection and transfer

Onboard systems must support low latency and high bandwidth data flow to the ground station. Berkeley DB is memory resident and multi-threaded with row-level locking for optimum concurrency and performance. It can integrate with 3rd party adapters, including low latency, high bandwidth DDS messaging middleware. The software supports both connected and disconnected modes.

At the ground station, adapters receive the network data and pass it to database buffer queues. Oracle TimesTen, in particular, excels at buffering high volumes of network data. The buffered inbound data is then routed and translated by an enterprise service bus. Oracle SOA Suite includes the Oracle Enterprise Service Bus, which supports very high bandwidth and sophisticated translation and routing of data via the underlying Streams technology in the Oracle Database.

Figure 3: Drilldown on Oracle SOA Architecture
Data integration and decision-making

Organize disparate information into a unified data model

The unmanned vehicles can deliver many types of data (e.g., spatial coordinates, metadata, image, video or spectral data) to the ground station, where it must be combined with maps of the area, building blueprints, images, photographs, documents, etc. The data management software in the ground station must be able to store and process these complex data models. Oracle Database 11g includes a new feature, Secure Files, which allows unstructured data (including large files, such as image and video) to be managed in the database, at raw device speeds. Oracle Database also includes built-in routines that automate and accelerate the processing of spatial data. All the UVS data can, therefore, be integrated together, while maintaining maximum performance.

Share information with other systems/organizations

Integrating the UVS data with support data often requires communicating with backend systems. This can require pulling data from other systems (e.g. map services), or pushing critical events to them (e.g. enemy target detected). Web Services compliant protocols provide an industry standard approach for this system-to-system communication. Oracle SOA Suite provides administrative control of the security and management of web services, ensuring enforcement of security practices such as WS-Security, SAML, and XML Signature.

For communication with older backend systems, Oracle also supports legacy transport and document protocols through packaged adapters, or 3rd party plug-ins.

Speed the decision process flow

The ground stations can leverage the Oracle SOA Suite (See Figure 3) to route and transform data via the Enterprise Service Bus (ESB), and use the BPEL Process Manager (BPM) to orchestrates the process flows. Together, these generate rule-based responses to inbound sensor data. These responses can be arbitrarily complex, including nested workflows and threshold alerts on historical trends; this latter function is part of Business Activity Monitoring (BAM).

Some processes do require human input (e.g. the decision to fire a UV weapon on a target). The BPM can notify the decision maker via a Web 2.0 portal or a mobile device. If no response is returned within a certain window of time, the BPM can escalate the approval to the next individual in the chain of command.
**Anticipate trends before they become problems**

In addition to inline processes, there are a number of maintenance and management processes required to manage a fleet of UVSs. Staff must analyze trends, such as failure rates, and take appropriate action. The software should alert staff when thresholds are exceeded. For example, an unusual series of sensor readings might trigger an alert to an analyst. They would then evaluate replacing the vehicle, requiring an analysis of the stock of available replacement vehicles and the history of such atypical readings, to determine patterns in time or geography. This requires guided navigation techniques to direct the analyst to important data trends. Oracle Business Intelligence Suite provides these tools, integrated with spatial displays and a powerful set of report generation tools.

**Maintain responsiveness under fluctuating loads**

UVS software architecture must be able to scale without impacting latency. Improvements in sensors and network bandwidth can greatly increase the data load; the number of unmanned vehicles can quickly increase; data sharing with backend systems can increase; and, more dynamically, there can be extreme peak loads during a crisis.

The needs of a small, remotely managed ground station, may be best satisfied by a system built with TimesTen and a lightweight configuration of Oracle middleware. A medium-sized ground station, however, may require an Oracle Database server or small cluster, with standby servers. While a very large ground stations, managing many unmanned vehicles, may require additional scaling. Both the Oracle Database and Application Server support grid architecture to ensure extreme scalability at both the data and service layers. Grids allow processing and storage devices to be dynamically added or removed and the load redistributed as the load changes.

For these very large systems, even greater scalability can be obtained by inserting an intelligent cache between the application layer and the data layer. This buffers the load on the data layer both during peak intake and heavy processing periods. Oracle TimesTen can provide such an all-purpose in-memory data cache to offload and extend the performance of the data layer. High-end scaling of the application tier (beyond just a cluster) has proved to be much more difficult than many had anticipated. Based on extensive research, Oracle Coherence was designed to solve this problem and has delivered numerous real-world successes in extreme transaction processing. Ground stations managing large numbers of unmanned vehicles can now rapidly integrate large amounts of data to provide their users with a strategic view.
Flexibility and Configurability

The rapid rate of change in the UVS field requires a software architecture that is flexible and adaptive. First of all, this requires a standards-based architecture, so that technologies can be easily plugged into the architecture. Oracle has made a strategic commitment to open standards; all layers of the Oracle technology stack comply with the appropriate open standards.

Secondly, the UVS architecture should abstract the business processes and rules outside of the coded services—order to allow rapid reconfiguration of processes, applications, technologies, and communication links. Oracle’s SOA Suite enables this flexibility so that UVS software can comply with SOA principles and key standards, such as Web Services and BPEL. Its ease-of-use and robust features maximize developer productivity and system configurability.

Security

Security is not an add-on feature to a software stack; it must be integrated into all layers. A single breach should not provide access to all the assets. There must be layers of defense, in which even “super users” are monitored by independent audits. Identity management must support various levels of authentication, from simple password to multi-factor (such as the Common Access Card (CAC)) and biometrics. This includes integration with existing security systems, such as LDAP synchronization or more sophisticated Federated authentication protocols (e.g. SAML) that large agencies require. Oracle Identity Management provides these features.

User identity must be passed down each layer of the stack to ensure application “super users” do not provide easy breach paths to all the data. Some UVSs with very sensitive data or missions may need to employ additional protection. Instead of just ensuring “who” is accessing the system, they may need to track the “where,” “when,” and “how” of user access. Irregular or suspicious access attempts may be blocked and then tracked. Oracle Database Vault limits data access based on a wide range of environmental factors. This is also the foundation for the Oracle Cross Domain Security Solution, which protects classified information shared by users on different networks: a feature critical to UVS data sharing in the military environment.

Reliability and Availability

The onboard software must be extremely reliable and capable of unattended operation. Oracle Berkeley DB runs directly in the application that uses it, so no separate server is required and no human administration is needed. Berkeley DB offers advanced data management services, including concurrent access, transactions and replication for high availability and fault tolerance. The software has been optimized over more than a decade of real-world deployments in mission-
critical applications. The caching, locking, logging and other crucial subsystems have been tuned to deliver outstanding performance without sacrificing reliability.

Ground station configurations vary significantly. Some ground stations need to be small, remotely managed systems, with no onsite support. These systems could be based on TimesTen with Replication, which ensures failure recovery by replicating transactions to a second server, either synchronously or asynchronously. This could be combined with pre-configured deployments of the Oracle Application Server, J2EE container and BPEL Process Manager. Recovery and failover would be automated, and maintenance remotely managed.

Larger ground stations could support additional functionality needed for a population of mission analysts. This would be configured with Oracle Database 11g, and support a larger set of middleware functionality. There would be full failover and recovery. For very large systems, a grid configuration would provide dynamic load balancing and online capacity growth. Remote backup sites would be kept synchronized via the Oracle Data Guard components of the Oracle Database.

Cost Reduction

Lower software costs

COTS products, such as the Oracle technology stack, provide a lower-cost, more reliable, mature and maintainable platform on which to build UVSs. Custom development should be focused on building the unique UVS processes and algorithms, rather than the infrastructure already available in COTS software. The cost of development can be further reduced by leveraging industry standard frameworks, such as J2EE, and by implementing them with integrated development environments, such as Oracle Developer.

Lower hardware costs

Grid architecture provides a scalable platform that can be built on low cost processors and storage devices. There are also compression, de-duplication and integrated lifecycle management features in Oracle Database 11g that can greatly reduce the cost of storage used. This is particularly important when UV sensors are gathering large amounts of image and video data.
CONCLUSION

This paper has illustrated how COTS software, from Oracle, can reduce UVS development time, cost and risk. In addition, the Oracle solution provides further value to the developers of UVSs. As an integrated suite from a single vendor, it eliminates much of the overhead for version control and system testing that is so costly when integrating technologies from multiple vendors. Secondly, the quality of the Oracle solution is reflected in its industry leading products. For instance, the Berkeley DB has over 200 million deployments, and TimesTen is the industry leader for systems that demand high performance, availability and unattended operations. Oracle technologies also receive high ratings by independent analysts. Gartner, for example, placed Oracle’s middleware in the Leader’s Quadrant for Application Infrastructure in its FY07 Q2 report. InfoWorld, described the Oracle SOA Suite as “The most comprehensive and easy-to-use product on the market today” in its January 22, 2007 review. The BI Suite and Coherence products are likewise highly rated in their respective categories. And with over twenty independent security evaluations for its products, Oracle is the undisputed leader in independent security evaluations.

Finally, Oracle brings the value of a strategic partner with extensive resources, one that is committed to open standards and sustained innovation. The UVS field will continue to expand, therefore it is critical to build with technology that is not only state-of-the-art today, but which will continue to be so in the years ahead.

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