23390: Deploying embedded computer vision systems on military ground vehicles
Ross Newman (Field Applications Engineer, Abaco Systems UK)
Abaco Systems advances the capabilities of the warfighter by providing game changing **mission ready embedded systems**, components and technologies to defense contractors.

Our products reduce program risk, allow technology insertion with affordable readiness, and ultimately help **platforms reach deployment sooner** with lower cost.
WE RELY ON A HIGHLY EXPERIENCED TEAM OF 800+ PROFESSIONALS WITH GLOBAL REACH
WE DELIVER COTS AND CUSTOM SOLUTIONS WITH LONG LIFECYCLE SUPPORT AND FIVE RUGGEDIZATION LEVELS

Lowest TCO
- Broader range of COTS options
- Best in class Technology Insertion capabilities

Rugged
- Temperature
- Shock
- Vibration
- Humidity & salt fog

Open standards
- VMEbus
- OpenVPX
- PC104 / PC104+
- PMC & XMC
- PCI & PCI Express
- CompactPCI
- PXI compatible

Minimal SWaP
- Advanced thermal solutions for fan-less cooling
- Wedgelock restraints
- Rugged military connectors & sealed enclosures
Deploying GPUs into military applications
Brief overview of military vehicle electronics (vetronics)

Electronic architectures provide significant benefits.
- Ability to meet mission objectives with increased operational capability.
- Reduce crew numbers through greater autonomy.
- Increase survivability (reduced loss of life).

Systems need to work together sharing information.
- Network enabled architectures.
- Optical systems moving to fully digital.
- Telemetry data storage (HUMS).
- Big data analytics.
- Layered security protocols.
- Secure data and RF communications.
- Situational awareness across the battlefield.
The argument for open standards / open architectures

Globally there are several initiatives that share a common set of goals. Reduced cost of ownership, interoperability, upgradability to allow for ‘bolt on’ new capabilities and allow for technology advancement and innovation.

- **VICTORY** Vehicular Integration for C4ISR/EW Interoperability
- **Generic Vehicle Architecture** (DEF-STAN 23-13)
- **NATO Generic Vehicle Architecture** (STANAG 4754)

This approach presents significant opportunity for COTS vendors to develop innovative product offerings that incorporate GPU/s performing various rolls within a vetronics system.

*NGVA is an extension of GVA that meets a broader set of requirements including unmanned systems integration
The Land Open Systems Architecture (LOSA) is the UK MOD’s approach for open systems across the land environment. GVA is the set of standards that apply to vehicles.

**Generic Vehicle Architecture (GVA DEF-STAN 23-09)**
- Fully Digital architecture
- Distributed Data Service (DDS)
- SNMP
- HUMS (allows for legacy bus/s MilCAN & CAN)
- Precision Time Protocol

**VIVOE (great for GPUs!!)**
- Vetronics Infrastructure for Video Over Ethernet (DEF-STAN 00-82)
- Real Time Protocol (RTP)
- Session Announcement Protocol (SAP)
- Raw streaming (uncompressed)
- JPEG 2000 streaming
- H.264 streaming

Vehicle programs: AJAX, Foxhound, F-ATV, Challenger 2, LEP, MRV-P, Warrior CSP, FPBA, LPMR, MIV
The NVIDIA Jetson TX series of embedded GPU and desktop GPUs are ideally suited for SWaP optimized applications within a vehicle. Roles for embedded GPUs within the vetronics architecture include:

Mission Computers
- Commander display – Mission objectives, moving map, data aggregation, situational awareness.
- Gunners display – Automated firing options, threat detection, image fusion, object classification and localization, segmentation.
- Drivers display – Real time low latency multicast video.

Storage
- Video server – Record and playback in real time
- Data server – Mission data, maps etc..
- HUMS (Health Usage and Monitoring Systems)
- Network Attached Storage – cryptographic

Gateway
- Protocol conversion – Edge of network, legacy interfaces
- Compression – Audio and video streams for RF transmission

AI & Deep Learning
- Increase autonomy in situational awareness
- Threat detection and identification
- Autonomous resupply
NVIDIA GPUs in today's military vehicles

AJAX
The world's first fully-digitized armoured fighting vehicle.
Exploiting the digital video standards
## Popular Digital Video Interfaces
### Comparison of Popular Digital Camera Interfaces

<table>
<thead>
<tr>
<th></th>
<th>FireWire 1394.a</th>
<th>Camera Link®</th>
<th>USB 2.0</th>
<th>USB 3.0</th>
<th>GigE</th>
<th>HD/3G SDI</th>
<th>GSML</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed</strong></td>
<td>800 Mb/s</td>
<td>3.6 Gb/s (full configuration)</td>
<td>480 Mb/s</td>
<td>5Gb/s</td>
<td>1000 Mb/s</td>
<td>3Gb/s</td>
<td>1.5Gb/s</td>
</tr>
<tr>
<td><strong>Cable</strong></td>
<td>100m (with GOF cable)</td>
<td>10m</td>
<td>5m</td>
<td>3m (recommended)</td>
<td>100m</td>
<td>300m</td>
<td>15m</td>
</tr>
<tr>
<td><strong>Channels</strong></td>
<td>up to 63</td>
<td>1</td>
<td>up to 127</td>
<td>up to 127</td>
<td>Unlimited</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Connector</strong></td>
<td>9pin-9pin</td>
<td>26pin</td>
<td>USB</td>
<td>USB</td>
<td>RJ45/Cat5e or 6</td>
<td>BNC (Coax)</td>
<td>Coax or STP</td>
</tr>
</tbody>
</table>
RTP example for video processing and storage

<table>
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<tr>
<th>Acquisition</th>
<th>Dissemination</th>
<th>Presentation</th>
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<td>Legacy video standards</td>
<td>Openware switch management software</td>
<td>Embedded (ARM) CPU</td>
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<td>Protocol conversion</td>
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<td>Out of band management</td>
<td>Compression H.264 / H.265</td>
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<td>10Gig video streaming</td>
<td>VICTORY switch compliant</td>
<td>Object classification</td>
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*GVC1000 Launch GTC San Jose 9th May  
**Future SWaP recording solution  
DDS = Distributed Data Service (Real Time Publish-Subscribe RTPS)  
SNMP = Simple Network Management Protocol
GigE Vision example for video processing and storage

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**Future SWaP recording solution
What is bayer8 and YUV?

Bayer (8 bits per pixel example)  YUV422 (16 bits per pixel)

Interpolation is used to reconstruct the image missing colour information.

Y’UV files can be encoded in 12, 16 or 24 bits per pixel.

The Y’UV model defines a color space in terms of one luma (Y’) and two chrominance (UV) components.

Luma values occur twice as frequently as chrominance U and V components i.e.

4 bytes repeat for 2 pixels:

YUYV YUYV YUYV

Commonly used in TV and analogue video.
RFC4175 - RTP payload format for uncompressed video.
Also mandated in GVA (DEF STAN 00-82)

OpenGL programmers will be used to RGB (Red, Green, Blue) buffers 24 bits per pixel where primary colours are represented separately but this is much less efficient when streaming.
For GigE Vision video acquisition then take a look at Aravis API and Gstreamer plugin.

Abaco systems GVC1000 deep learning demo with TensorRT uses PointGrey cameras for video ingress and Aravis for acquisition with colour space conversion being done using Abaco’s ImageFlex functions for real time video.

**Note:** bayer plugin can be found in gstreamer bad plugins.

```bash
sudo apt-get install gstreamer1.0-plugins-bad
```

RTP streaming is described in RFC4175 - RTP Payload Format for Uncompressed Video.

RTP raw streaming is supported in Gstreamer and can be demonstrated using the YUV colour space using the pipeline below:

```bash
gst-launch-1.0 udpsrc address=239.192.1.44 port=5004 caps=application/x-rtp, media=video, clock-rate=90000, encoding-name=RAW, sampling=YCbCr-4:2:2, depth=8, width=640, height=480, payload=96 ! rtpvrawdepay ! queue ! xvimagesink
```

**NOTE:** Use appsink to get video into your application. xvimagesink renders the stream on the display in a window.

Aravis is found on [https://github.com/AravisProject/aravis](https://github.com/AravisProject/aravis)

More information on Gstreamer can be found on [https://gstreamer.freedesktop.org](https://gstreamer.freedesktop.org)
Why do we need 10Gig Ethernet?

Military applications demand high quality uncompressed real time video and audio streaming. Video compression adds additional latency and compression artefacts limiting its used in military applications.

<table>
<thead>
<tr>
<th>Defaults</th>
<th>Height</th>
<th>Width</th>
<th>Colour Space</th>
<th>FPS</th>
<th>Bandwidth (Mb)</th>
<th>Channel(s)</th>
<th>Total (Mb)</th>
<th>Megapixles / sec</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>640x480</td>
<td>640</td>
<td>480</td>
<td>Bayer8</td>
<td>30</td>
<td>9.00</td>
<td>27</td>
<td>243.00</td>
<td>248.83</td>
<td></td>
</tr>
<tr>
<td>1280x720</td>
<td>1280</td>
<td>720</td>
<td>Bayer8</td>
<td>30</td>
<td>27.00</td>
<td>9</td>
<td>243.00</td>
<td>248.83</td>
<td>HD 720p</td>
</tr>
<tr>
<td>1920x1080</td>
<td>1920</td>
<td>1080</td>
<td>Bayer8</td>
<td>30</td>
<td>60.75</td>
<td>4</td>
<td>243.00</td>
<td>248.83</td>
<td>HD 1080p</td>
</tr>
<tr>
<td>3840x2160</td>
<td>3840</td>
<td>2160</td>
<td>Bayer8</td>
<td>30</td>
<td>243.00</td>
<td>1</td>
<td>243.00</td>
<td>248.83</td>
<td>4K</td>
</tr>
<tr>
<td>640x480</td>
<td>640</td>
<td>480</td>
<td>YUV</td>
<td>30</td>
<td>18.00</td>
<td>27</td>
<td>486.00</td>
<td>248.83</td>
<td></td>
</tr>
<tr>
<td>1280x720</td>
<td>1280</td>
<td>720</td>
<td>YUV</td>
<td>30</td>
<td>54.00</td>
<td>9</td>
<td>486.00</td>
<td>248.83</td>
<td>HD 720p</td>
</tr>
<tr>
<td>1920x1080</td>
<td>1920</td>
<td>1080</td>
<td>YUV</td>
<td>30</td>
<td>121.50</td>
<td>4</td>
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<td>1</td>
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<td>248.83</td>
<td>4K</td>
</tr>
</tbody>
</table>

**NOTE:** H.264 and H.265 compression is most useful where bandwidth is limited such as RF links and off vehicle secure transmission.
Now we have the video what next?

- Deep Learning, inference at the edge.
- Advanced image processing ISP and compression
- Data parallelism using CUDA for situational awareness

*AXIS ImageFlex sensor fusion
*SkyBox running on the GVC1000
Abaco Systems NVIDIA GPU enabled products
Hardware - Fully ruggedized board level GPUs

High Performance OpenVPX NVIDIA Pascal architecture. Choose OpenVPX form factor for easy integration and future proofing GPU upgrade path via technology insertion.

Tegra ARM/GPUs for low power embedded applications. Choose embedded for low Size Weight and Power (SWaP)

| Embedded Tegra SoM | 3U VPX Desktop (GPU Only) | 6U VPX Desktop (CPU + GPU) |
Hardware - Packaged Products with NVIDIA GPUs

Fully integrated board sets ready to deploy (Zero NRE) featuring NVIDIA GPUs.

GVC1000 (Jetson TX2)  
GVC2000 Lightning (GM107 + Xeon CPU)
Software - AXIS enabled middleware for GPU enabled DSP applications

Dataflow
- AXIS View: ApplicationView
  - Define dataflow
  - Visualize dataflow

High Performance Communication Libraries
- AXIS Flow
  - Proprietary
  - Thread Based
- AXIS MPI
  - Open Standard
  - Process Based

Performance Analysis
- AXIS EventView
  - Demystify App Perf

Application GUI
- AXIS DataView
  - Control C Variables
  - Visualize App Data

High Performance DSP Libraries
- AXIS RSPL
  - Proprietary
- AXIS VSIPPL
  - Open Standard

Advanced Integrated Software Development Tool Suite
Perhaps the industry's most advanced, most intuitive embedded software development environment, AXIS enables rapid software development.
Software - NEW AXIS ImageFlex dedicated visualization API with GPU acceleration.

- **ImageFlex Visualization framework API**
  - Image creation and management
  - CPU to GPU data movement
  - 2D “overlay” drawing Image processing API
  - Image manipulation
  - Lens distortion correction
  - Complex image morphing
  - Image fusion
  - Image stabilization Interoperability API
  - CUDA / OpenCL interoperability API Custom extendibility
  - Easy creation of custom OpenGL “shader”
  - 2D and 3D Matrix computation functions. Abaco quick start application examples
  - “Basics” example, showing all key functionality
  - “SkyBox” example for spherical situation awareness
  - Image fusion example
  - Image stabilization example
  - OpenCV and OpenVX interoperability examples

**Advanced Integrated Software Development Tool Suite**

Perhaps the industry’s most advanced, most intuitive embedded software development environment, AXIS enables rapid software development.
Autonomous capabilities

Abaco’s defence pedigree enables autonomy safely.

**COMPUTE CAPABILITY** + **SAFETY** + **SECURITY** + **ENVIRONMENTALS** + **PROCESS TRACEABILITY**
Our vision is to be your embedded partner of choice as you design and deploy mission-critical systems for the harshest, most challenging environments.

INNOVATE
Fresh, new thinking to create better ways of solving problems

DELIVER
We live up to our commitments. Time after time. Every time.

SUCCEED
Our business only succeeds when our customers succeed. Period.