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Introduction

• UAVs have been in use primarily by government agencies in the United States while the European UAV market is more focused on commercial, scientific, and civil applications.

• Continued investment and technological advancements for UAVs have generated an increased interest in a variety of potential applications in wireless communications, environmental management, industrial inspection, and civil protection.

• Key to the market growth of these UAV applications is the development of payload sensors and systems in a reduced form factor and lighter weight than what is typically used in manned aircraft.

• Microelectronics and device packaging play an important role in the continued development and growth of the US and European UAV payload market.
UAVs are projected to be the most dynamic growth sector for the nation’s aerospace industry over the coming decade.

Studies project the marketplace to more than double with worldwide UAV research, development, test and evaluation, and procurement expenditures.

Overview of UAVs in Commercial Markets
Commercial Markets for UAVs:
Agriculture and law enforcement comprise the majority of the demand over the next decade

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Sales Forecast for Civil and Parapublic UAS ($M) 2012 – 2024, Frost & Sullivan 2012

Tentative Outlook for Civil UAS Production, 2015 - 2022

Composites Forecasts and Consulting LLC, 2013
Examples of Commercial Markets for UAVs

**Oil Spill Monitoring**

- High portability of smaller platforms makes regulating the unprofessional/underground industry problematic.
- First commercial operations in the Arctic permitted by the FAA.
- Improved energy storage technology: Endurance battery = longer missions over greater distances.
- Synthetic aperture radar.

**Earth Science**

- Thin, high-efficiency solar cells give solar power for longer range and endurance.
- Public perception presents a serious risk to commercial uptake of UAS.
- Small carbon footprint, low operating costs, miniaturisation of sensors, minimum pilot skill, regulations.
- Lack of reliable, small-size powerplants, lack of certified systems, costly insurance.
- Interferogram of Mexican earthquake and Polariometric image of ice from UAV/SAR.
- L-band POLSAR – Hill enable observations of longer range & duration.
- Laser technologies.
- Certification for fully autonomous operation in un-segregated airspace.
- Requirement for standardised ground operations equipment able to service multiple platforms.

Source: NASA Jet Propulsion Laboratory and Frost & Sullivan.

Frost & Sullivan, 2013
Examples of Commercial Markets for UAVs

HAZMAT Detection

- Decreased risk to personnel
- Low operating costs
- Technological developments
- Regulations
- Privacy concerns
- Noise pollution

- GPS Waypoints, 3D flight terrain, laser altimeter, multiple vehicle control possible
- Target tracking and local recognition
- Sense and avoid technology

- Camera Turrets, HD Video, FLIR and night vision, SAR and LiDAR
- Autopilot requires minimum operator training
- Greater structural strength and decreased weight through next generation materials and manufacturing procedures

Source: Frost & Sullivan

Agricultural Monitoring

- Commercial operations are still prohibited in the US; however, agricultural small-size UAS are permitted in Europe, Australia, Japan, New Zealand, Brazil, and Mexico
- Low-cost components and manufacturing methods reduce platform price
- High flexibility
- Low operating costs
- Decreased loss of product yield
- Minimum operator skill

- 3D cameras, infrared, spectrometer, multispectral, hyperspectral, and thermal imaging
- Lightweight airframe, folds for portability
- Fully autonomous operation
- GPS Navigation, airspeed sensor

Source: Frost & Sullivan

Frost & Sullivan, 2013
Current status of commercial UAS deployment varies across the globe – the US lags behind the EU, Mexico, Canada, and Brazil due to a lack of FAA guidelines and privacy concerns.

- The shift to commercial implementation has been and will be gradual.
- Government and law enforcement have begun the shift, pressuring regulatory bodies to finalize interim legislation.
- This will facilitate the commercialization of UAS into numerous commercial and parapublic markets.

Where Regulations Have Passed:

- Countries with more relaxed UAS laws are good candidates for commercialization studies and are the proving ground for developed technologies.
- Agricultural UAS flights permitted.
- Aerostat: The Antares RPA awarded 1st permit to operated in non-segregated airspace.
- Goslar, Germany: Research Project RESGU proposed for non-restrictive UAS use.
- First RPAS in shared airspace.
- UAS development and use encouraged.
- No direct laws that prohibit civilian use. First Experimental Flight Certificate granted to Xirobotics for UAV Nauru 500.
- Regulatory processes restrain commercial growth in all but a select few countries.

Frost & Sullivan, 2013
UAVs for Google and Facebook

Both Google and Facebook recently acquired UAV companies to deliver the Internet via drones. Both companies will work with Internet.org to provide internet access to two-thirds of the world’s population. Internet.org will employ free-space optics on low-earth orbit satellites and long-endurance, high-altitude drones to provide connectivity.

Google acquired Titan for an undisclosed sum in April 2014.

Facebook acquired UK-based Ascenta for $20M in February 2014.

Only 1 out of every 3 people can go online.
Why aren’t more people connected?
Wireless Communications: Connectivity using UAVs

• Creation of new networks
• Expand current networks without adding infrastructure
• Provide critical communication access during natural or man-made disasters
• Several new and planned UAV projects in the commercial and government markets involve longer flight time (days, not hours) and not distance
• Google and Facebook are positioning themselves early to take advantage of the coming “mobile” infrastructure wireless network
UAV Sensor Payloads: EO/IR, Video, and Hyperspectral Imaging
The global UAV payload market is estimated to increase to US$6 billion by 2022, representing a CAGR of 4.3% during the forecast period.

Market demand will be driven by increased UAV procurement from several countries across the world.

Improvement requirements will continue in areas such as persistent surveillance, electronic countermeasures, communications relays and search and rescue which will also drive the market demand for UAV payloads.
UAV sensor payloads can perform some of the same tasks as those on manned aircraft. Our partnership with customers has resulted in the successful deployment of systems and equipment that sense and convert an external analog environment into data used for:

- Locating / Tracking
- Analysis
- Large Scale Computation
- Broadband Communication
UAV Payloads Contain Sensors, Communications, and the Electronics to Collect and Control the Generated Data

UAS sensors and subsystems include:

- Electro-optical/infrared (EO/IR)
- Lasers (LADAR)
- Light detecting and ranging (LIDAR)
- Signals intelligence sensors
- RADAR
- Communications radios / data links
- Vehicle control mechanisms:
  - Autopilots
  - GPS navigation modules

Many of the sensors and subsystems are utilized in both government and commercial UAVs. US-based microelectronics and packaging suppliers need to provide low-cost, dual-use solutions to compete with European suppliers.
Having an open architecture to accommodate modular sensors for quick and cost-effective integration is a key component in the development of advanced ISR capabilities for government and commercial applications.
E/O, RF Payloads, and non-avionic subsystems/sensors are the main areas within a UAV system where the microelectronics and packaging supply chain can provide value to the evolving UAV market as platforms get smaller without sacrificing data acquisition, processing, or secure transmission.
Photonics companies like Headwall Photonics, IMEC, along with several others are planning to leverage their expertise and intellectual property as the market transitions from government / space to commercial applications. The remote sensing market segment was estimated at $650M in 2014.

- Integrated hyperspectral imaging solutions will soon be available for:
  - Commercial UAVs
  - Specialty crop monitoring and analysis
  - Other industrial, medical applications

A close-up of Headwall Photonics’ Micro-Hyperspec sensor, which is optimized to be small enough and sufficiently light enough to be carried by easy-to-maneuver UAVs.

The company plans to offer even lighter-weight sensor payloads (<0.5 kg) using a 2-board approach with an FPGA and image sensor for higher resolution in a smaller form factor.
Hyperspectral Imaging: Current vs. New Technology

A conceptual drawing shows an example of a hyperspectral camera today (a) and a new integrated system (b) in which an objective lens is combined with the image sensor and a hyperspectral filter structure that is directly post-processed on top of the image sensor.
Hyperspectral Imagers for UAVs – Pros and Cons

**Pros**

One of the biggest advantages of hyperspectral imaging is in the detail it can provide. An infrared sensor or multispectral sensor, for example, might only indicate the presence of a target of interest.

A hyperspectral sensor, however, might indicate not only the presence of a target, but also the kind of metal it's made from, the color and type of paint it has, or the amount of moisture it contains.

**Cons**

Sometimes the sheer amount of electro-optical (EO) information a hyperspectral sensor can provide poses major digital signal processing (DSP) challenges.

In fact, many of today's hyperspectral sensor systems are designed to match detected target signatures against libraries of known hyperspectral signatures.

In the future, however, experts say DSP technology most likely will improve to meet the demands of real-time hyperspectral imaging systems, and the resolution of today's hyperspectral sensors will improve.
Packaging for UAV Payloads
Packaging for Commercial UAV Payloads

- The commercial UAV market will continue to be extremely cost sensitive
- Standard package outlines will be utilized whenever possible
- Harsh operating environments, special signal processing requirements can be accommodated with a cost vs. performance analysis and package material options

Organic packages and PCBs

Ceramic packages

PCBs with embedded components
Addressing the Need for UAV Image Processing: GPUs, CPUs

In 2006, incorporation of GPU’s and CPUs to process image data resulted in amazing performance gains of one to two orders of magnitude for a variety of applications such as georegistration, hyperspectral imaging, speech recognition, image processing, bioinformatics, and seismic exploration. However, a recent survey by Mercury Systems in Chelmsford, MA revealed that processing the enormous amount of sensor data and fusing the data together is still a challenge.
Addressing the Need for UAV Image Processing: GPUs, CPUs

Mercury Systems is developing a system that integrates multiple GPUs together with FPGAs and will allow for rapid upgrades as new, higher performance GPU technology becomes available.

- Billions of pixels/sec
- High GFLOPS for complex real-time image-processing
- SWaP constrained

- Billions of pixels/sec
- High GFLOPS (1 GFLOP = 1 billion floating point operations/sec)
- SWaP constrained (SWaP = Size, Weight and Power)
Addressing the need for more image processing in smaller UAVs will require highly-integrated light-weight modules.

To achieve a high-degree of image processing in a smaller form-factor, a higher computing capacity, standard interfaces, and moving the processor closer to the sensors (from ground station to UAV), and making the electronics smaller is required.

The UAV industry is still faced with the SWaP, volume data processing, and signal integration challenges according to the Mercury Systems survey. US microelectronics suppliers need to provide solutions for integration and thermal management to be competitive.
Summary

• The government market for UAVs will remain steady for the next decade at least, despite budget cuts.

• The commercial or dual-use market opportunities are predominately outside of the US in the EU, Australia, Canada, Brazil, and Mexico.

• The commercial UAV market in the US will not see much growth until the FAA determines the rules for sharing the airspace and the Sense and Avoid radar systems are fully functional and deployed on all UAV platforms.

• Regardless of whether the market is commercial or government, low-cost solutions will be needed to be competitive with foreign competitors and to comply with the government procurement directives for UAV systems. Taking a proactive position in advance of market growth should enable the microelectronics and packaging supply chain to provide cost-effective solutions.