MICROELECTRONICS AND PACKAGING FOR UAV PAYLOADS

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Market Development

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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.
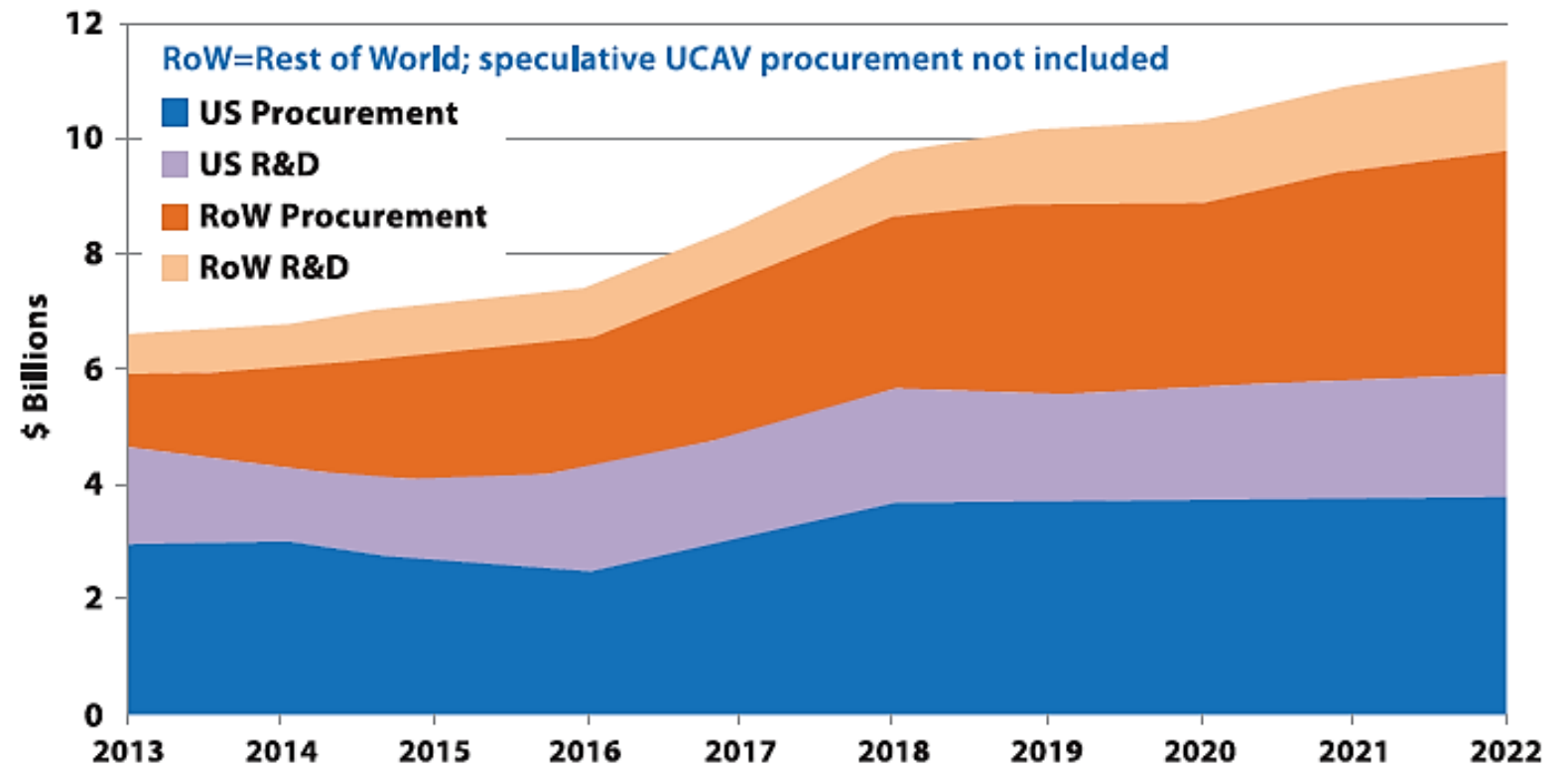
Market Forecast

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.

World UAV Budget Forecast
R&D and Procurement

RoW=Rest of World; speculative UCAV procurement not included

- US Procurement
- US R&D
- RoW Procurement
- RoW R&D

$ Billions

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

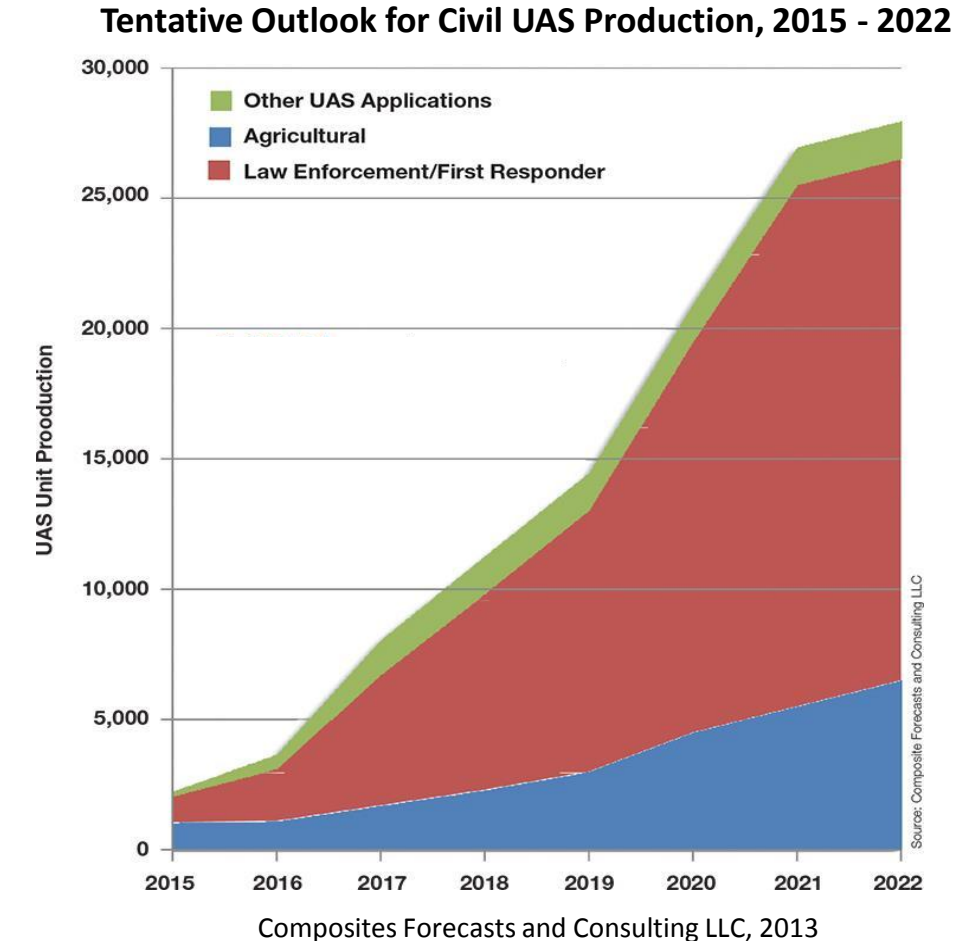Source: "World Unmanned Aerial Vehicle Systems." Teal Group. April 2012

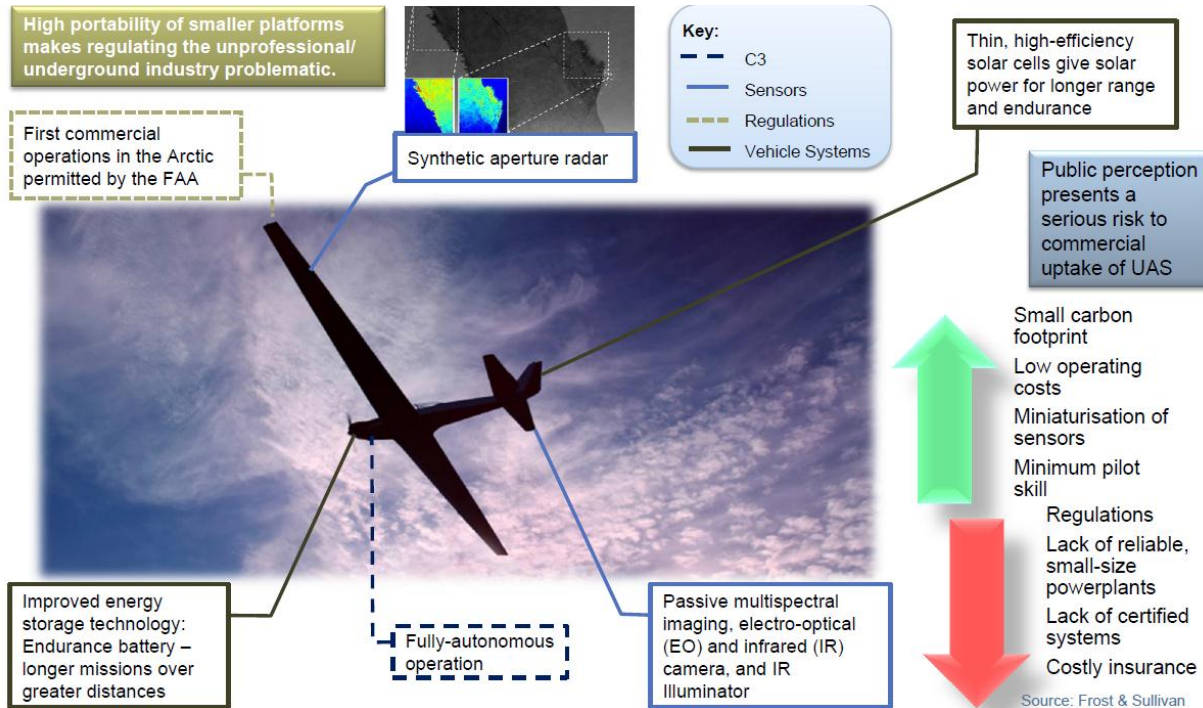# Overview of UAVs in Commercial Markets

Commercial Markets for UAVs:

Agriculture and law enforcement comprise the majority of the demand over the next decade

	2012	2016	2020	2024
First Responders	24.2	150.3	213.2	120.2
Agriculture	0.1	131.7	355.5	321.3
Forestry	0.1	0.3	0.9	3.3
Port Authority/Shippers	0.0	0.0	0.4	2.9
Mining and Minerals	0.0	0.0	1.2	5.5
Oil and Gas	0.0	0.0	0.7	2.8
Environmental Compliance	0.1	0.4	4.1	16.6
Natural Disasters	0.0	0.2	0.5	3.0

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

High portability of smaller platforms makes regulating the unprofessional/ underground industry problematic.

First commercial operations in the Arctic permitted by the FAA

Synthetic aperture radar

Key:
- - - C3
— Sensors
- - - Regulations
— Vehicle Systems

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

Improved energy storage technology: Endurance battery – longer missions over greater distances

Fully-autonomous operation

Passive multispectral imaging, electro-optical (EO) and infrared (IR) camera, and IR Illuminator

Source: Frost & Sullivan

Key:
- - - C3
— Sensors
- - - Regulations

Fully autonomous operation

Synthetic aperture radar interferometry for seismic monitoring

High-speed data downlink to relay sensor readings

L-band POLSAR –Will enable observations of longer range & duration

Laser technologies

Certification for fully autonomous operation in un-segregated airspace

Ka-band radar and LiDAR for vegetation and ice structure monitoring

Requirement for standardised ground operations equipment able to service multiple platforms

Inteferogram of Mexicali earthquake and Polarimetric image of ice from UAVSAR

Source: NASA Jet Propulsion Laboratory and Frost & Sullivan

Oil Spill Monitoring

Earth Science

Frost & Sullivan, 2013

Examples of Commercial Markets for UAVs
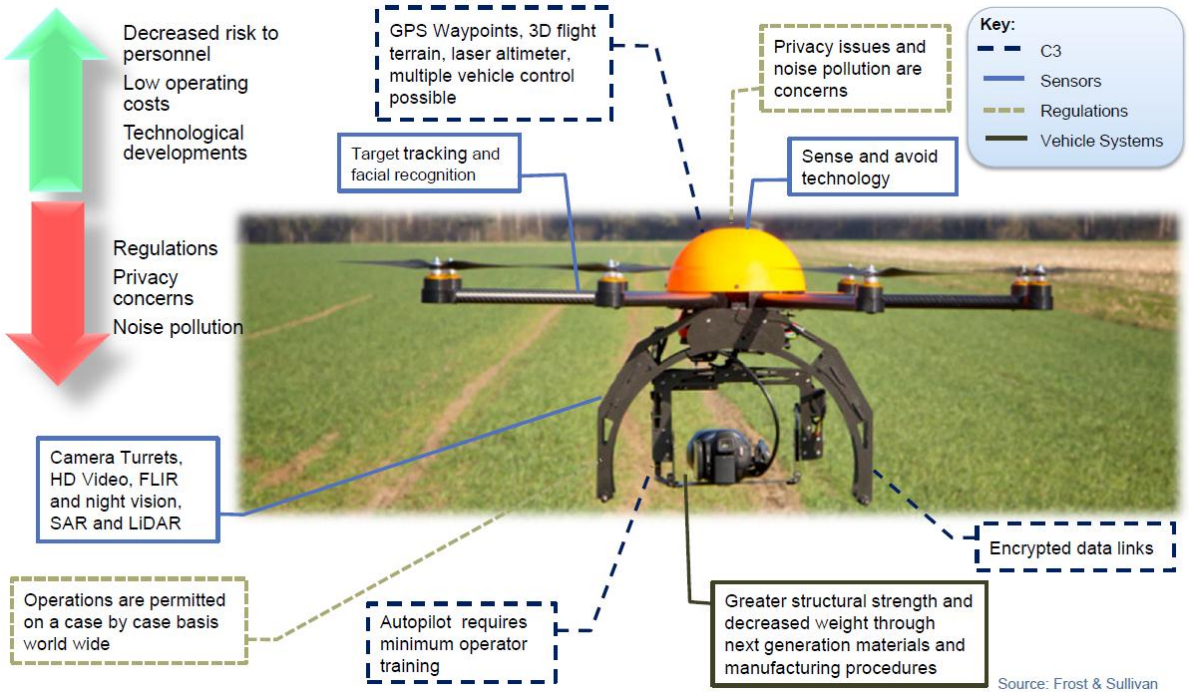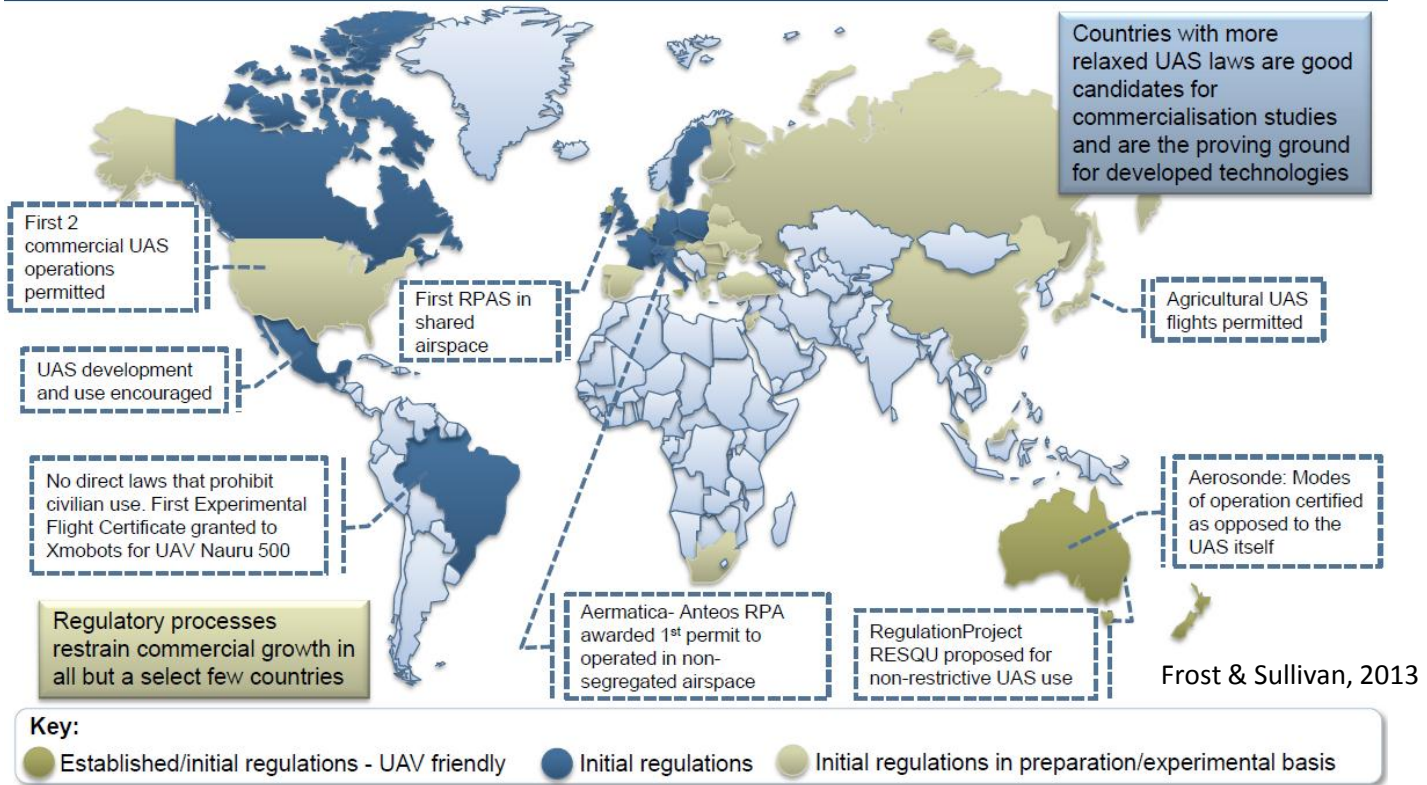

HAZMAT Detection

Agricultural Monitoring

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 commercialisation studies and are the proving ground for developed technologies

First 2 commercial UAS operations permitted

First RPAS in shared airspace

Agricultural UAS flights permitted

UAS development and use encouraged

No direct laws that prohibit civilian use. First Experimental Flight Certificate granted to Xmobots for UAV Nauru 500

Aerosonde: Modes of operation certified as opposed to the UAS itself

Regulatory processes restrain commercial growth in all but a select few countries

Aermatica- Anteos RPA awarded 1st permit to operated in non-segregated airspace

RegulationProject RESQU proposed for non-restrictive UAS use

Frost & Sullivan, 2013

Key:
- Established/initial regulations - UAV friendly
- Initial regulations
- Initial regulations in preparation/experimental basis

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

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

Wireless Communications: Connectivity using UAVs
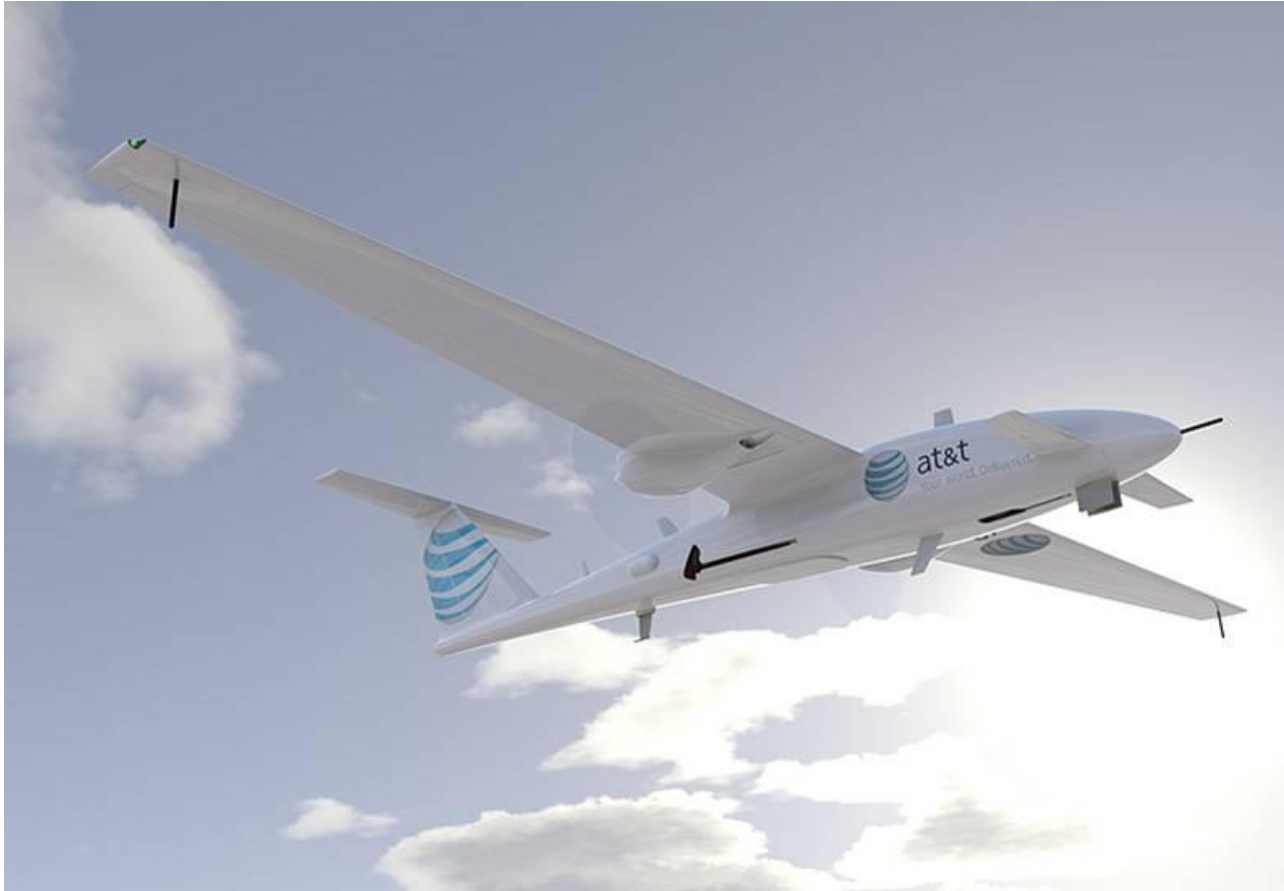
- Creation of new networks
- Expand current networks without adding infrastructure
- Provide critical communication access during natural or man-made disasters
- Several new and planned UAV projects in the commercial and government markets involve longer flight time (days, not hours) and not distance
- 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

Global UAV Payload Market ($B) 2012 - 2022

Global UAV Payload Market 2012 – 2022
CAGR 4.3%

Source: SDI Analysis, 2012

© SDI
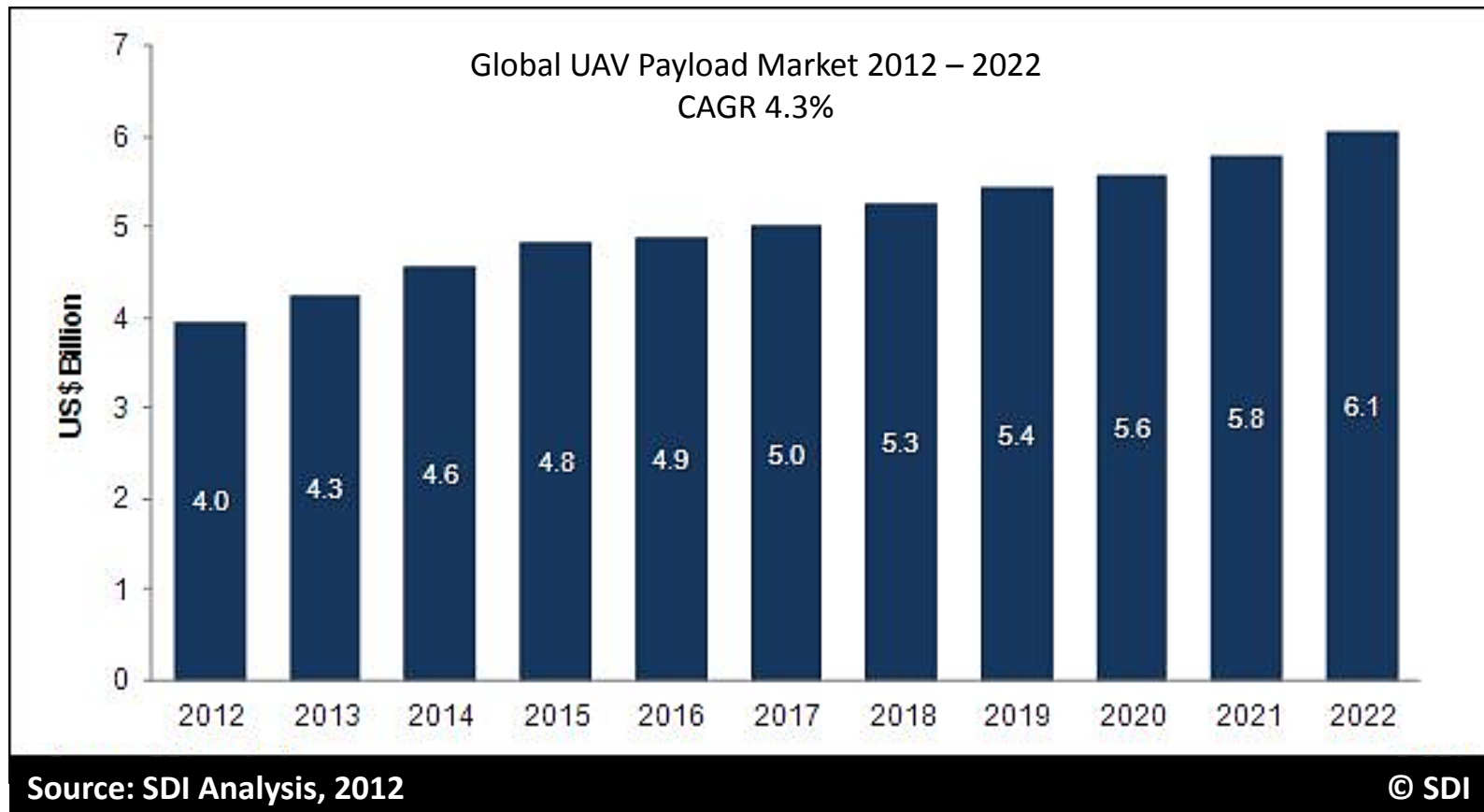
The global UAV payload market is estimated to increase to US$6 billion by 2022, representing a CAGR of 4.3% during the forecast period.

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
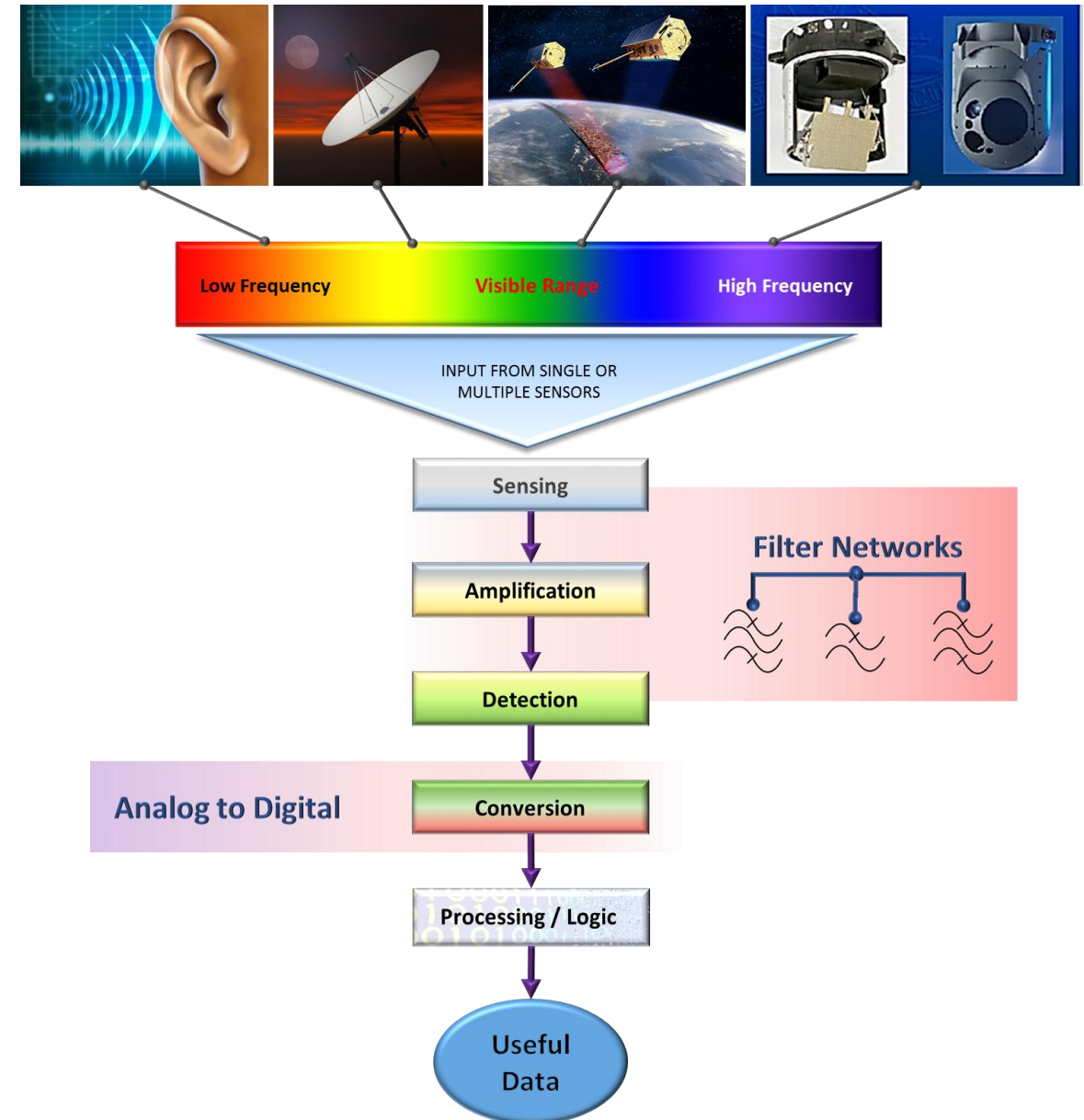
UAV Payloads Contain Sensors, Communications, and the Electronics to Collect and Control the Generated Data

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
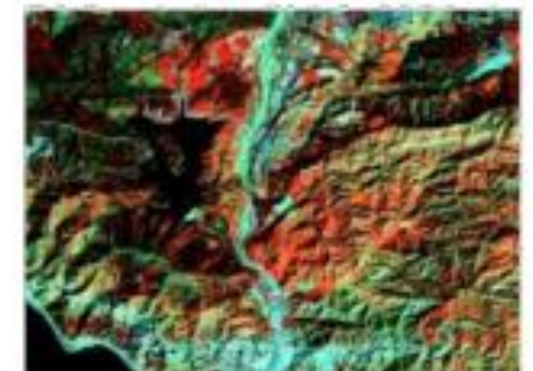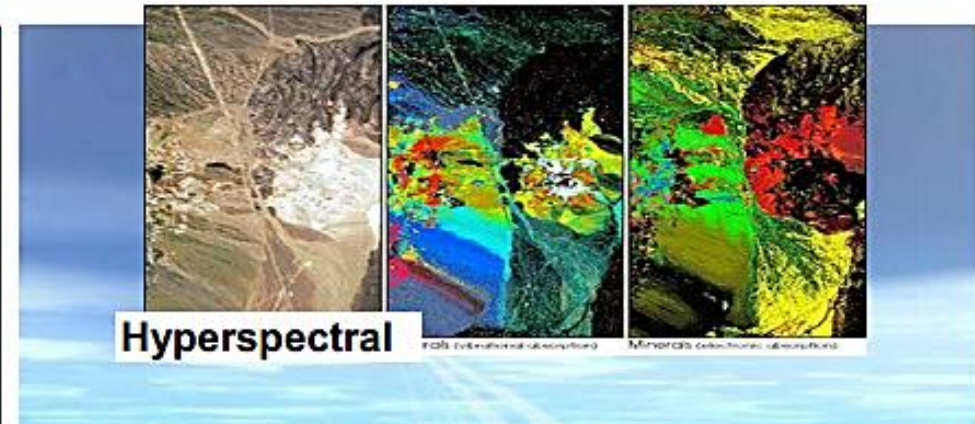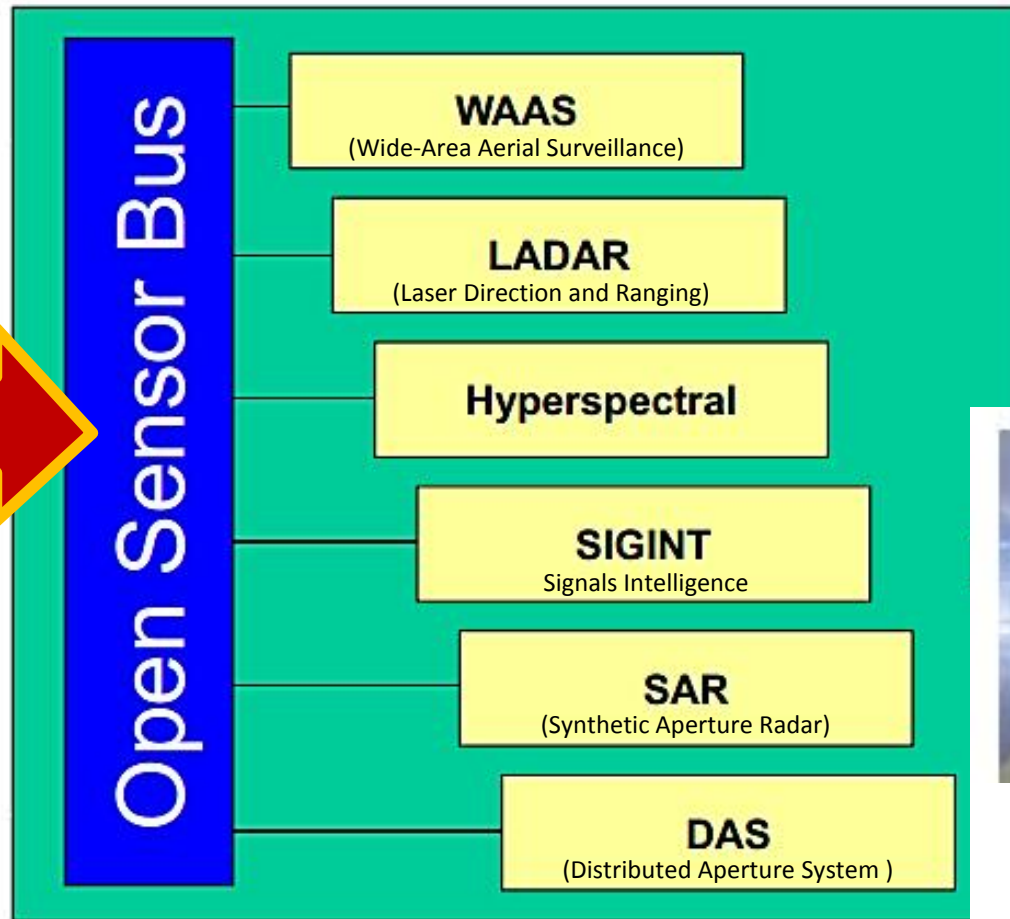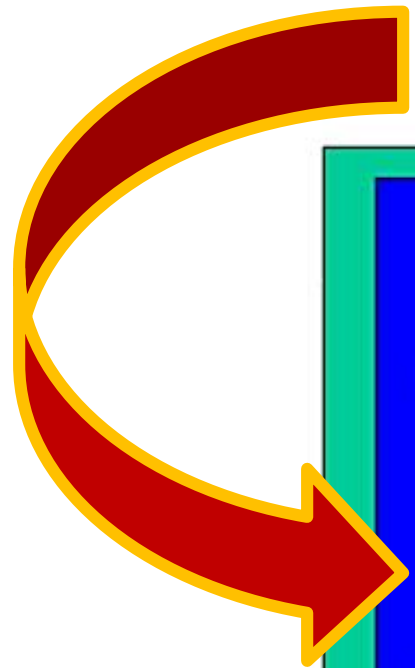
Avionics Architecture Example for Long-Endurance UAVs
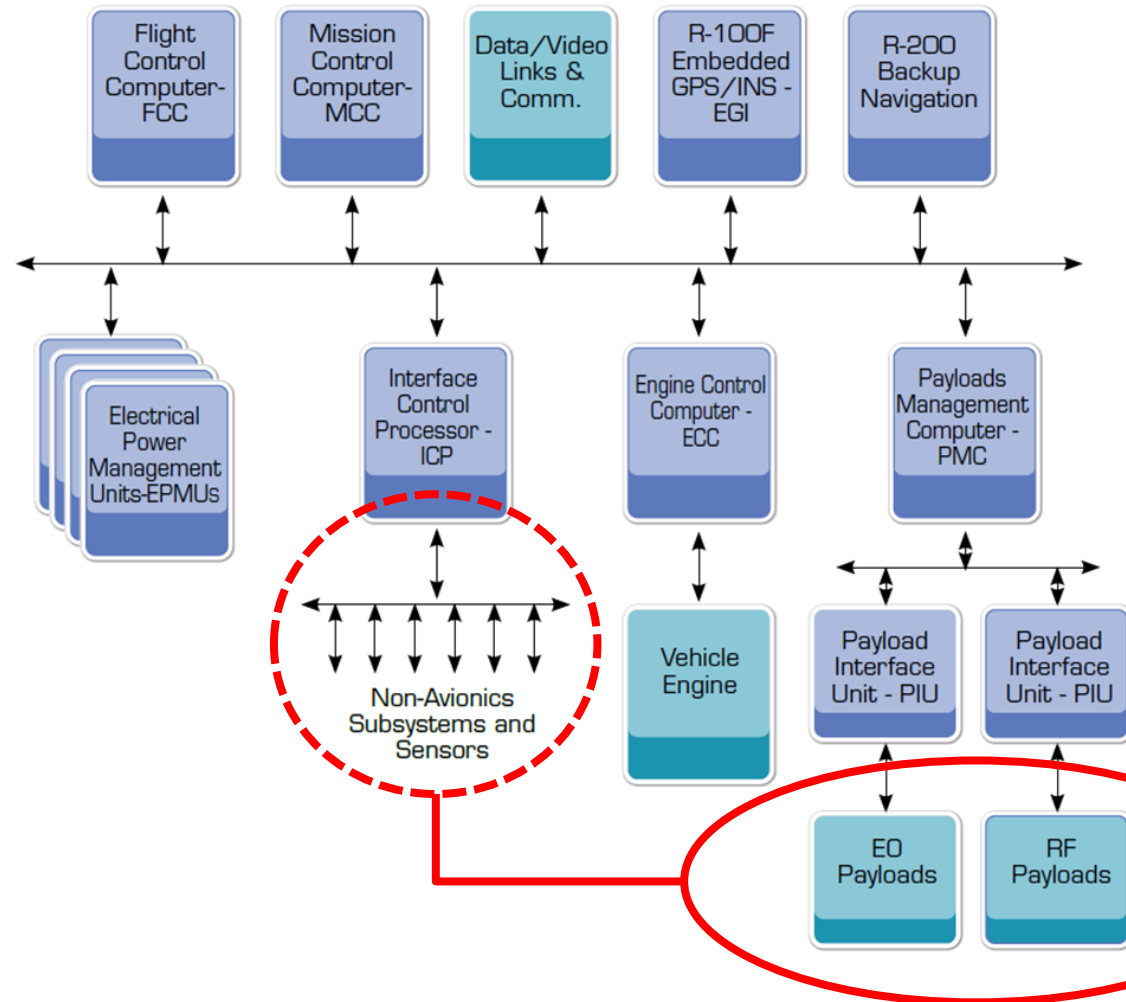
E/O, RF Payloads, and non-avionic subsystems/sensors are the main areas within a UAV system where the microelectronics and packaging supply chain can provide value to the evolving UAV market as platforms get smaller without sacrificing data acquisition, processing, or secure transmission

RADA Industries, 2011

Hyperspectral Imaging for Commercial Markets

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**

Headwall Photonics Website, 2014

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.
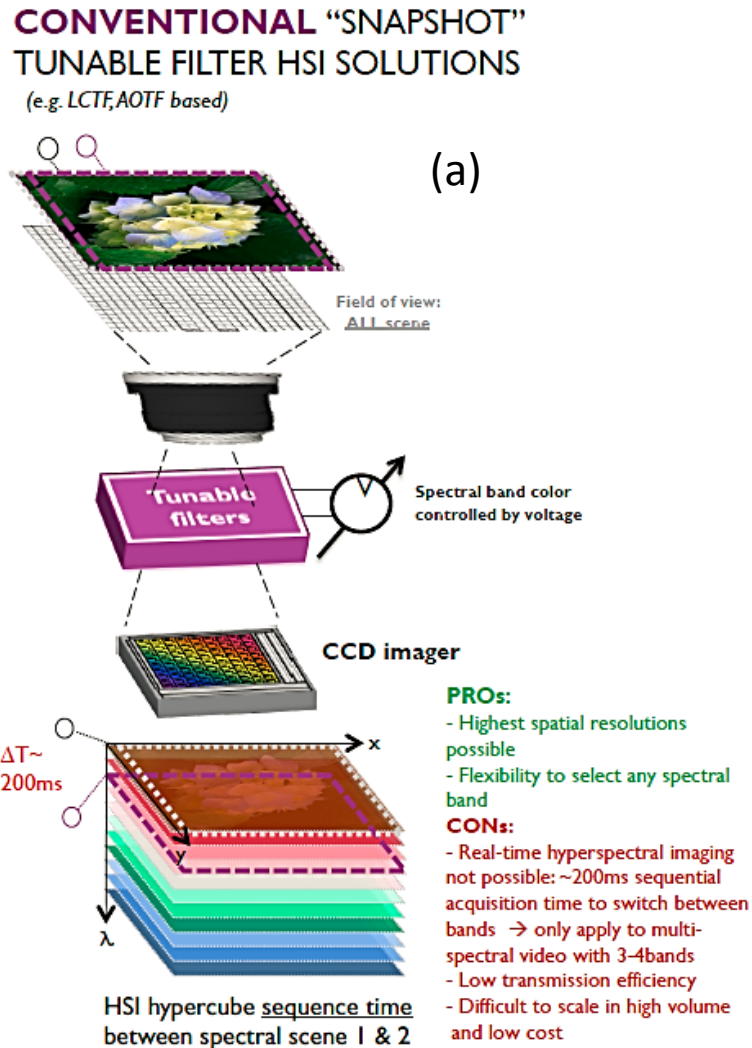
Courtesy of IMEC
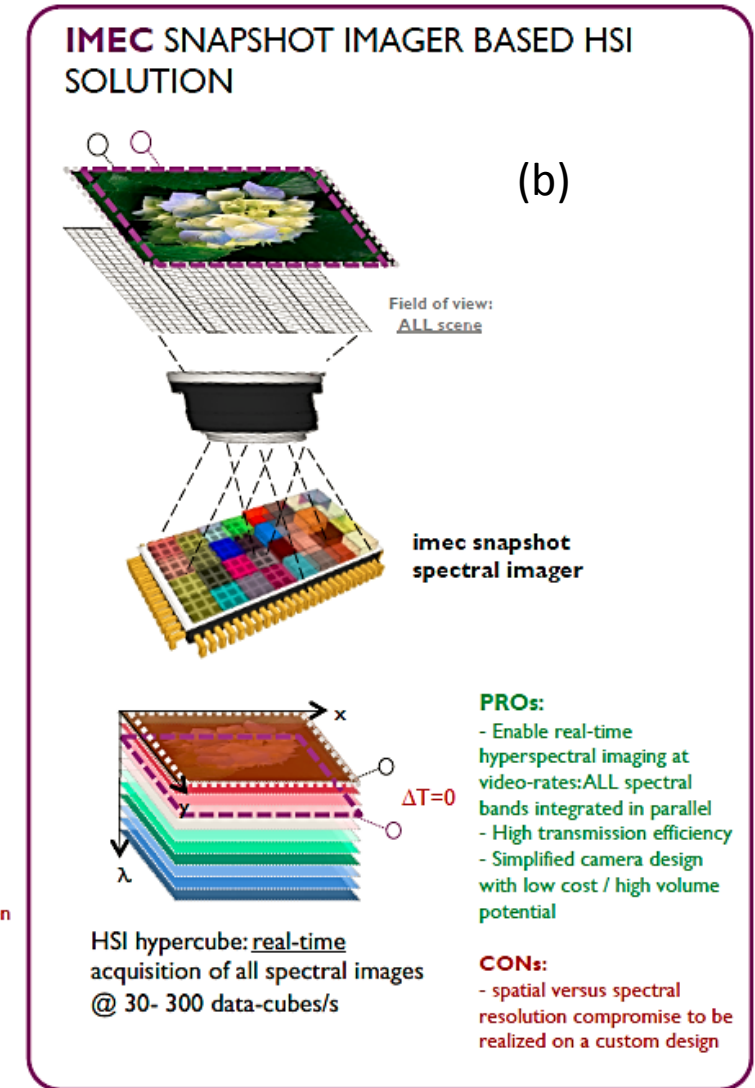
Hyperspectral Imagers for UAVs – Pros and Cons

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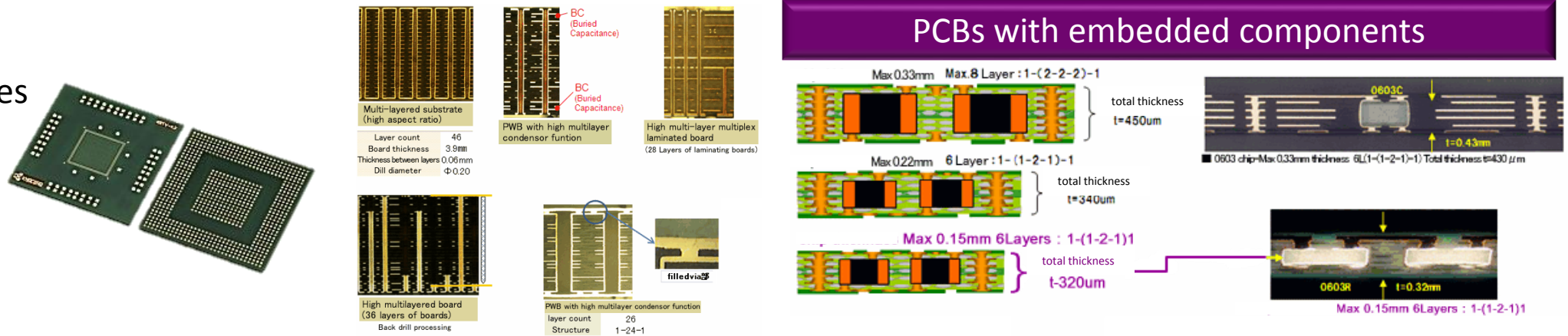
In the future, however, experts say DSP technology most likely will improve to meet the demands of real-time hyperspectral imaging systems, and the resolution of today's hyperspectral sensors will improve.

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
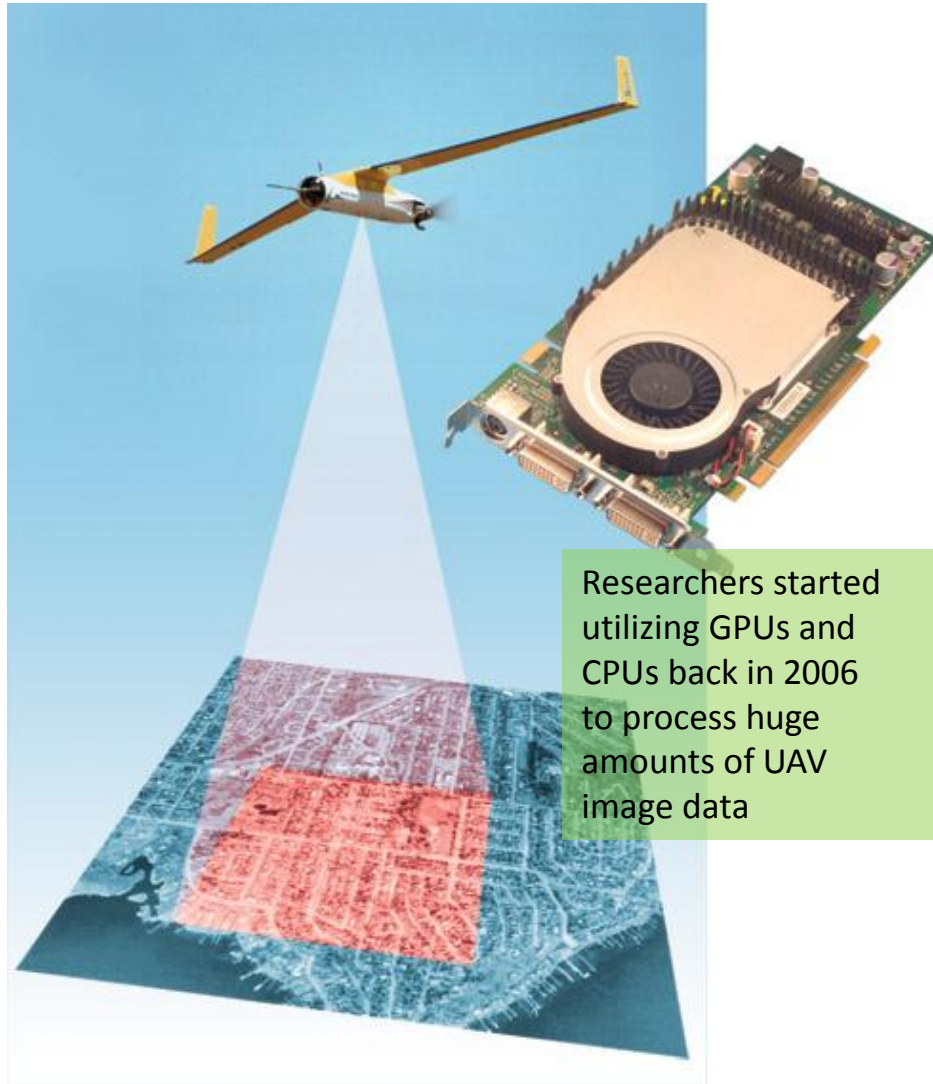
Organic packages and PCBs

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.

Researchers started utilizing GPUs and CPUs back in 2006 to process huge amounts of UAV image data

Recent (2012-2013) survey conducted by Mercury Systems

Addressing the Need for UAV Image Processing: GPUs, CPUs

EO/IR Image Processing Subsystem
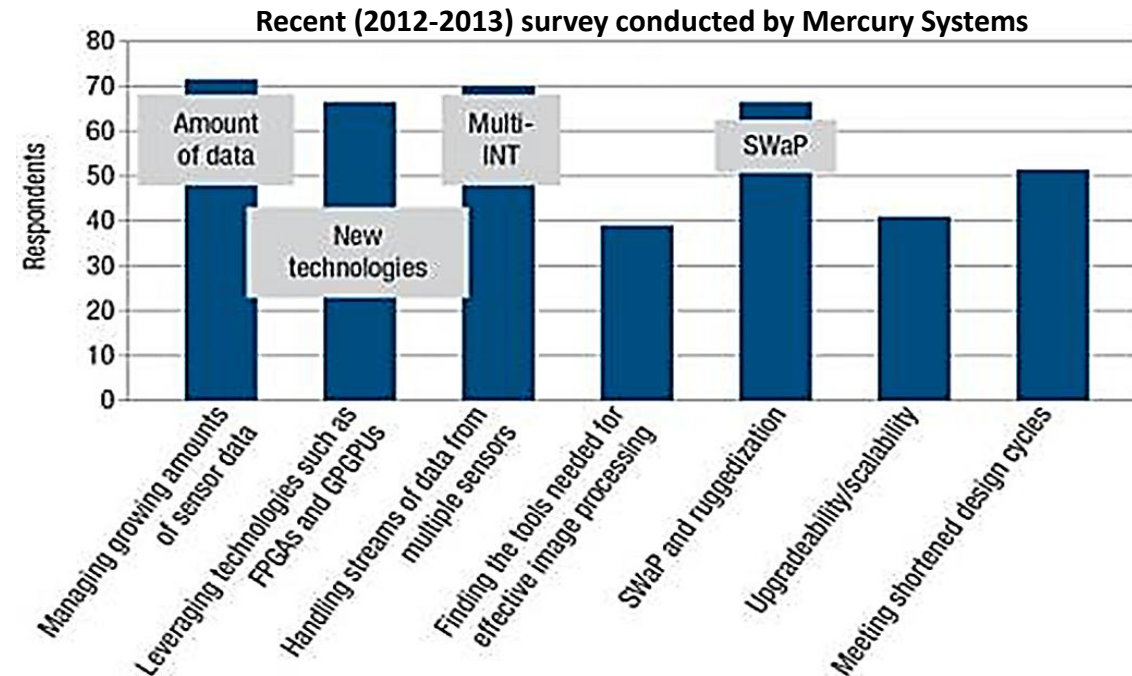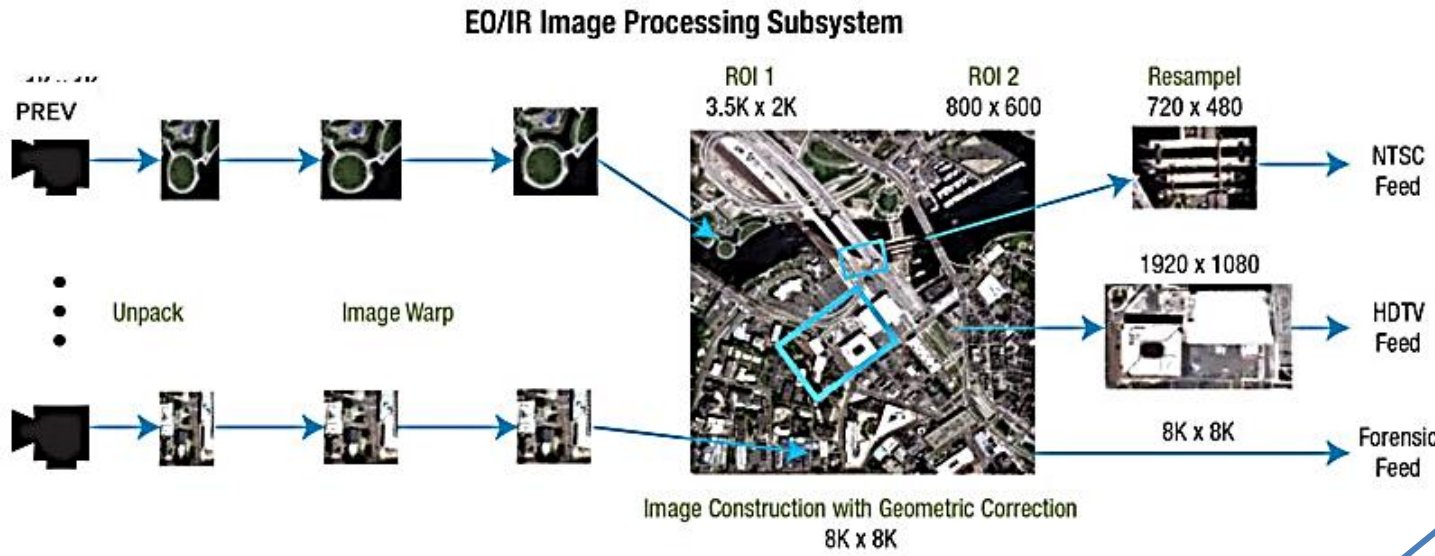
- Billions of pixels/sec
- High GFLOPS for complex real-time image-processing
- SWaP constrained

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 (1 GFLOP= 1 billion floating point operations/sec)
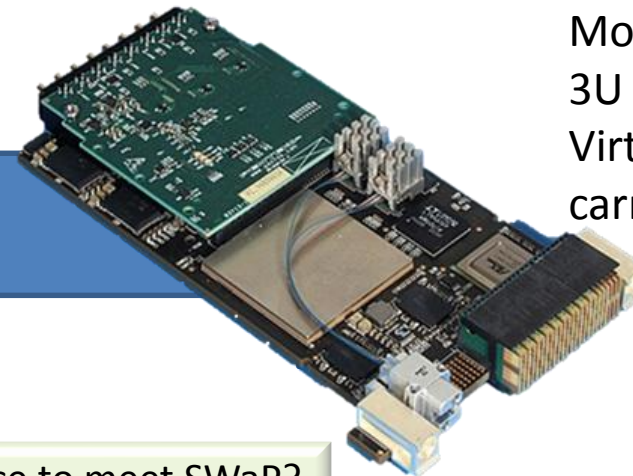- SWaP constrained (SWaP=**S**ize, **W**eight **a**nd **P**ower)
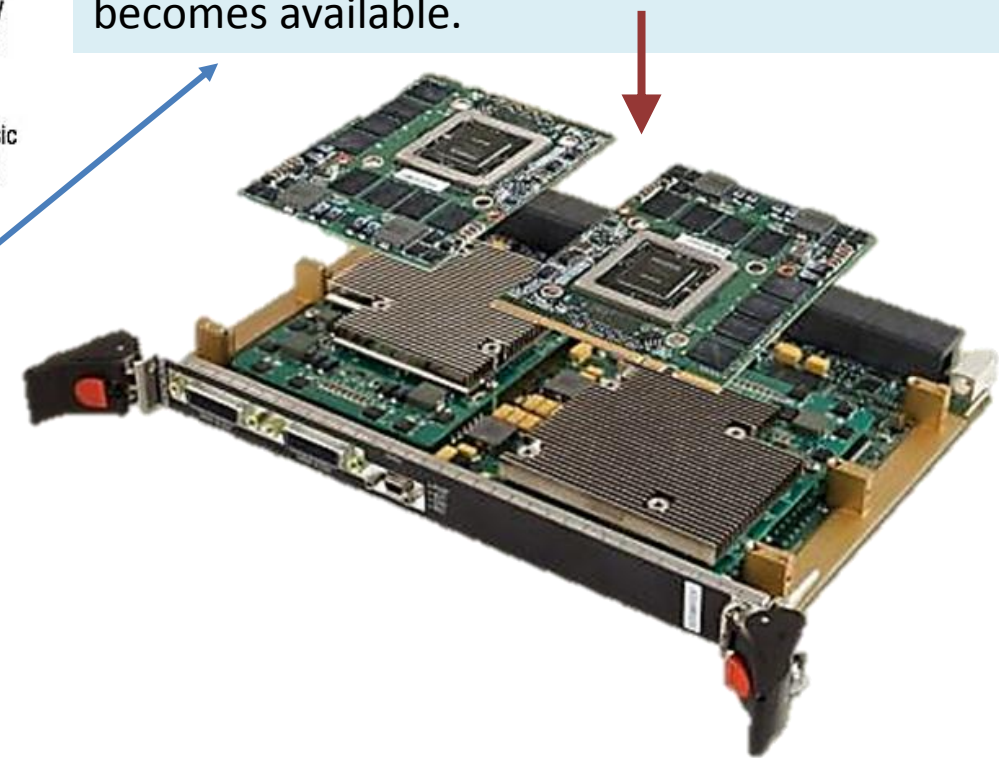
Addressing the need for more image processing in smaller UAVs will require highly-integrated light-weight modules

High Performance Embedded Computing (HPEC) used with large UAVs

The Pentek Model 5973 3U VPX Virtex-7 FMC carrier

?

Package / Module / Interface to meet SWaP?

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