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TRENDS FOR UNMANNED AERIAL VEHICLE MISSIONS and PAYLOAD TECHNOLOGIES

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ABSTRACT

Unmanned Aerial Vehicles (UAVs) have a wide range of applications with a diversity of payload systems. The design and development of UAV payload systems is of critical importance in order to have a successful mission.

This paper aims; to identify the main UAV missions, technological trends in UAV payloads and also to give insight on the design and development activities in ASELSAN Radar, Electronic Warfare and Intelligence Systems (REHIS) Division regarding the UAV radar and electronic warfare payloads. ASELSAN REHIS Division has developed a UAV Synthetic Aperture Radar, capable of image generation in strip-map and spot-light modes and also target detection in Ground Moving Target Indicator mode. Additionally, ASELSAN REHIS Division has research and development activities in radar and communications electronic warfare payloads. The performance of ASELSAN's compact electronic support and electronic attack systems are already operationally proven on multiple manned aircraft and rotorcraft platforms.

This paper indicates that in order to have smaller size, lighter weight and less power consuming payloads not only technologies related to the UAV payload elements i.e.; technologies for antenna, receiver, processor, transmitter, etc. are evolving, but also new operational concepts are being developed to utilize weight and power budget more efficiently, such as multi functional radio frequency systems. The future will put even more focus on size, weight and power and also on generation of new concepts.

INTRODUCTION

Unmanned Aerial Systems (UAS) are "system of systems" consisting of the Unmanned Aerial Vehicle (UAV), payload system, ground control system, launch and recovery system and data links. UAV, being one of the main "system" of the "system of systems" is defined as; a powered, aerial vehicle that does not have a human operator on board, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely **[US DoD, 2005].**

For any "system of systems" the requirements for each and every system should be set at the very beginning. However for the UAS, it is generally the case that "payload system" ends up having to fit to the requirements posed on it by the "UAV". This is so, because the ever changing military requirements – which have been the main drivers for the development of UAVs – has resulted in the UAVs' being forced to fulfill different missions. Moreover, the development of a new UAV airframe is generally much more expensive than developing new payloads and customizing the requirements of the payloads to that of the airframe. For a typical strategical purpose UAV with surveillance and reconnaissance mission, a rough breakdown of development costs is 48% for airframe, 20% for avionics and communications and 32% for payload **[Austin, 2010].**

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There are various classifications for the UAVs, the most common being in operational range and altitude aspects. Table-1 indicates the most commonly acceptable UAV classification **[Blyenburg, 1999].**

Category	***Range (km)***	***Flight Altitude (m)***	***Endurance (hours)***
Tactical UAVs			
MICRO (μ)	<10	~250	~1
MINI	<10	~350	<2
Close Range (CR)	10-30	~3.000	2-4
Short Range (SR)	30-70	~3.000	3-6
Medium Range (MR)	70-300	3.000-5.000	6-10
Medium Range Endurance (MRE)	>500	5.000-8.000	10-18
Low Altitude Deep Penetration (LADP)	>250	5.000-9.000	1-2
Low Altitude Endurance (LAE)	>500	~3.000	>24
Medium Altitude Long Endurance (MALE)	>500	5.000-8.000	24-48
Strategical UAVs			
High Altitude Long Endurance (HALE)	>1.000	15.000-20.000	24-48
Unmanned Combat Aerial Vehicles (UCAV)	400-500	~20.000	~2

Table 1: Classification of UAVs by Range and Altitude

PAYLOAD SYSTEMS

Sensors or equipment, carried by the UAV, dedicated to perform the specific mission assigned, are commonly called as "payloads". UAVs, though have both military and civilian missions; have experienced the main challenges by the former. The main UAV military missions are; Surveillance and Reconnaissance, Signals Intelligence (SIGINT), Electronic Warfare (EW), Suppression of Enemy Air Defense (SEAD), Strike, Communications Support, Chemical and Biological Agent Detection, Mine Detection. UAVs, even have been dedicated for a specific mission in the past, are increasingly being used for multi-missions. Table-2 indicates a relation between the payloads and the UAV missions.

UAV Mission	Payloads													
	EO/IR Imaging System	Electronic Intelligence System	Communications Intelligence System	Radar Electronic Support System	Radar Electronic Attack System	Communications Electronic Support System	Communications Electronic Attack System	Communications Relay System	Radar System	Chemical/Biological Sensors	Spectroscopy	Light Detection and Ranging	Guidance/Designation System	Munitions and Missile System
Surveillance& Reconnaissance	■								■					
Signals Intelligence		■	■	■		■								
Electronic Warfare				■	■	■	■							
SEAD				■	■									
Strike	■			■									■	■
Communications Support								■						
Chemical/Bio. Agent Detection	■									■	■	■		
Mine Detection	■								■					

Table 2: UAV Mission and Payload Relation Matrix

UAV payloads have mission critical importance. The main technical factors that drive the design and development of the UAV payloads can be summarized as **[Austin, 2010]:**

- the range, endurance and altitude required in the operation of the UAV,
- mass and drag constraints,
- field of view requirements,
- range and area of surveillance needed,
- type of target,
- resolution of the imagery,
- accuracy of target parameter measurement,
- need for recording

The size and mass of the payload and its requirement for electrical power are often the main determinant of the layout, size and total mass of the UAV. Furthermore, electromagnetic compatibility requirements (payload-payload and payload-UAV flight equipment interactions) are other concerns that UAV payload designers should handle at system level.

UAV payload design and development is a complex and iterative process in which platform modifications are required to improve the UAV mission success probability **[Henselmann and Hoffmann, 2008].** The UAV payload development process is summarized in Figure – 1 below.

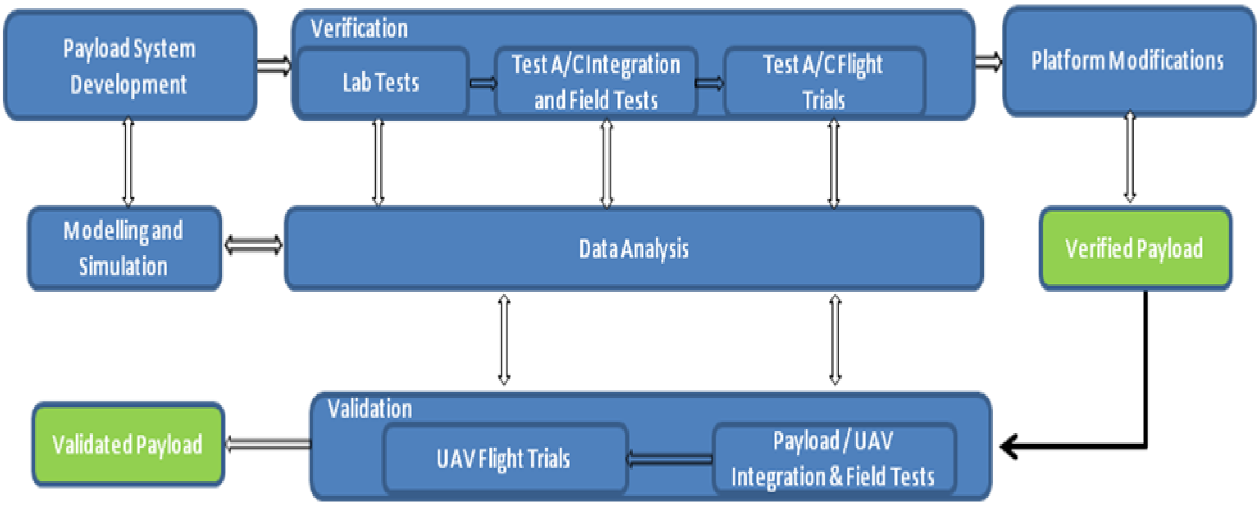

Figure 1: UAV Payload Development Process

UAV Mission Trends

UAVs have various civilian applications. Most notable civilian applications are; surveillance, search and rescue, damage assessment, border patrol, meteorological services, agricultural services and forest fire detection.

For military applications, most of the UAV missions tend to be on Surveillance and Reconnaissance. Surveillance and Reconnaissance can be defined as; “mission undertaken in order to have information about the activities and resources of an enemy or potential enemy; or to secure data concerning the meteorological, hydrographic or geographic characteristics of a particular area” **[NATO, 2010].** The use of UAVs for Surveillance and Reconnaissance mission can be traced back to the early 1960s. In July 1960, the U.S. Air Force initiated a new project, code named “Red Wagon”, to demonstrate a modified “Firebee” target drone that would perform remote-controlled photographic surveillance missions. “Firebee” was operational during the 1962 Cuban Missile Crisis, the photos provided revealed the locations of surface-to-air missile sites[3] **[Cook, 2007].**

The majority of the UAV Surveillance and Reconnaissance missions are accomplished at stand-off ranges and at high altitudes which also require long endurance. However, high altitude and stand-off missions pose limitations for high resolution imagery. This limitation can be overcome by close in

[3] In 1962 Cuban SA-2 Surface to Air Missile downed a manned US Air Force U-2 aircraft over Cuba.

missions which can reduce the complexity of the sensing technology used and very high resolution imagery can be achieved.

UAV missions increasingly spread on SIGINT and EW. SIGINT mission comprise of either individually or in combination of all intelligence derived from communications signals (communications intelligence) and radar signals (electronic intelligence). EW, in the broad sense means any military action involving the use of electromagnetic energy to control the electromagnetic spectrum effectively and it covers three subdivisions as; electronic protection, electronic support and electronic attack. Electronic protection involves passive and active means taken in order to protect friendly forces from any effects of electronic warfare that can degrade or neutralize friendly combat capability. Electronic support involves the actions in order to search for, intercept, identify, find direction of and geo-locate sources of radiated electromagnetic energy for the purpose of immediate treat recognition, targeting or threat avoidance. Finally, electronic attack involves the actions taken to prevent or reduce the enemy's effective use of the electromagnetic spectrum such as jamming and electromagnetic deception. For UAV EW missions, electronic support and electronic attack stands out as main payloads for both communications and radar systems. The first use of UAVs for SIGINT mission can be traced back to 1963 – 1973 Vietnam War, during which Ryan Aeronautical AQM-34 "Lightning Bug" executed electronics intelligence and real time communications intelligence missions **[Jones, 1997].**

For radar systems the return signal from the threat shrinks proportional to $1/R^4$, whereas for SIGINT and electronic support payloads the signal from the threat shrinks proportional to $1/R^2$. This inherent range advantage of SIGINT and electronic support payloads enables them to cue other systems that have shorter ranges and/or more restricted fields of view. The concept to detect and locate the emitter within a wide area via SIGINT/EW systems, and then utilize electro-optical payloads for the identification is becoming very common in today's applications.

The stand-off SIGINT and electronic support system payloads face limitations regarding the interception and detection of weak signals in relatively long ranges. On the other hand, close in operating UAVs may provide operational advantage in these missions. Figure 2 shows the tradeoff between geo-location error and range for a variety of direction finding payload accuracies. The figure clearly indicates that situational awareness and targeting level accuracies are more likely to be achieved by using SIGINT/electronic support payloads with modest capabilities, if close in range capability can be achieved.

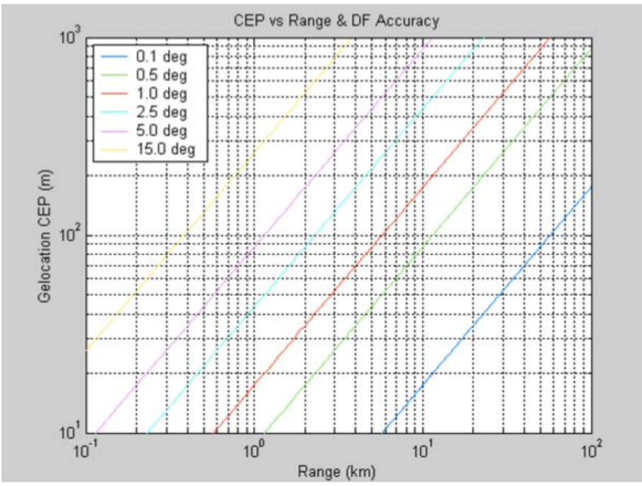

Figure 2: Geolocation Error versus Range for 0.1-15 degree RMS Accuracy Direction Finding Payloads

For electronic attack missions, i.e. for jamming, the significance of the proximity to the threat radar can be exemplified by the mini radar electronic attack payload developed by the Naval Research Laboratory. The payload produces 50 miliwatt jamming signal with 250 Megahertz bandwidth for 4 hours operating in S band (2 – 4 GHz) and with a weight of 20 grams. This payload within 500 feet of nominal 1 Megawatt Effective Radiated Power, S band radar, with an instantaneous bandwidth of 1 Megahertz, could screen a 1 square meter radar cross section aircraft to within a range of 10 kilometers from the radar **[Coffey and Montgomery, 2002].** If this were to be accomplished with a jammer at 200 miles stand off range then it will require an Effective Radiated Power of 207 kilowatts.

UAVs also evolve to be an option for SEAD and Strike missions. SEAD mission aims to destroy, degrade or cause malfunctioning of surface based enemy air defense systems and Strike mission can be defined as an attack intended to damage on, seize or destroy an enemy object. UAV systems deployed in advanced strike missions aim to destroy surface based enemy air defense systems in advance of attacks by manned aircraft and so can provide combat support. The first demonstrated capability of the Strike UAVs is declared as the BGM-34 “Firebee” with two AGM-65 Maverick missiles having electro-optical guidance in 1970s **[Ehrhard, 2010]**. However the publicly being known of the UAVs for Strike mission is achieved by the engagement of RQ-1B Predator armed with laser guided Hellfire missiles in Afghanistan to Al Qaeda and Taliban targets in 2001 **[Sauer and Schörnig, 2012].**

For UAVs with Strike missions the widely used weapons are the air to ground missiles with laser, radar, GPS, IR guidance or multimode guidance. Research goes on the integration of electromagnetic pulse weapons to UAV platforms. **[Franklin, 2008], [Wilson, 2004]**. Electromagnetic pulse - an intense energy field that can instantly overload or disrupt numerous electrical circuits at a distance - can be candidate weapon for UAVs with SEAD capability. However, the use of electromagnetic pulse has self-destruction issues that need to be further worked on. Strike UAVs also generally include electro-optical payloads in order to have battle damage assessment capability to make certain that the engaged threat has been eliminated **[Langham and Zanker, 1997]**.

Destroy or neutralization of enemy aircraft and missiles, by air to air missiles launched from the UAVs seems to be available in the near future, even not yet operationally demonstrated on the battlefield. Predator had launched a Stinger air-to-air missile at an Iraqi MiG before the Iraqi aircraft shot it down at March 2003 **[Fulgham, 2003]**. Long endurance for situations in which manned aircraft would be unable to sustain effective operation and the survivability assets to be installed on the UAVs would the main drivers which support the case for unmanned air to air combat missions **[Frampton, 1997].**

Communications Relay mission aims to expand communication links far beyond the Line of Sight range of V/UHF radios primarily over urban and mountainous terrain. This was considered as a secondary mission of a UAV deployed for other main missions and turns out to be the main mission of smaller UAVs in order Communications Relay, providing secure and third generation telecommunications uplink and downlink **[Pinkney, Hampel and DiPierro, 1996].** This mission can also have potential civilian applications.

Monitoring the release of chemical and/or biological agents is of considerable concern both in conventional warfare and in warfare against terrorism. Most of the UAVs intended for this mission tend to be Mini UAVs. Chemical agent detectors used on Mini UAVs rely on surface acoustic wave sensors and electrochemical cells. Similarly most of the biological warfare payloads collect samples at remote distances and return them to a qualified laboratory for biological agent detection testing. Payloads based on Ion Mobility Spectrometry enable the detection, identification and tracking of chemical plumes **[Cao, Harrington and et.al, 2004]**. Ion Mobility Spectrometry Systems ionize the vapors of the chemical compounds and then the ions are separated on the basis of their mobility within an applied electric field. However, these payloads tend to be much bigger than to be carried by the Mini UAVs. Signal processing techniques to provide low susceptibilities to false alarms, and real time in situ testing for the agents tends to be a widely operated research area regarding the chemical/biological payloads.

Mine Detection is an emerging area for the UAV payloads. Detection of buried items can be possible by the use of infrared/hyper spectral sensors which detect anomalous variations in electromagnetic radiation reflected or emitted by either surface mines or the soil and vegetation immediately above buried mines. Thermal detection methods exploit diurnal variations (i.e. after dawn and before sunset, when the surface temperatures are changing) in temperatures of areas near mines relative to surrounding areas. Non-thermal detection methods rely on the fact that areas near mines reflect light (either natural or artificial) differently than surrounding areas **[Gooneratne, Mukhopahyay and Gupta, 2004].** In addition to the thermal imagers, research is going on the detection of land mines by ground penetrating synthetic aperture radar systems **[Goad, Schorer and et.al, 2008].** However, due to the complex nature of the burried mine detection problem, multisensor detection and data fusion seems to get much attention. Detection and fusion algorithms are still to be evolved for the minimization of false alarms for mine detection.

In addition to the above mentioned common military applications, there exist also some rare applications. One is the use of UAVs for detection of gunshots, which has always been a challenge for both military and law enforcement agencies. Acoustic sensor arrays capable of detecting the acoustic signature of the gunshots and optical or electro-optical sensors capable of spotting the visible signature have potential applications as UAV payloads **[Snarski, Scheibner, and et.al. 2006]**

As the mission of the UAVs gets more complex and more diversified, EW stands for a vital role in the protection of the growingly high value UAVs. This necessitates the use of EW self protection systems enabling the UAV to protect itself from infrared, laser and radio frequency based threats. EW self protection systems can be said to become essential especially for the strategic and MALE tactical UAVs. Especially for the UAVs with SEAD and Strike missions both “stealth” and “EW self protection systems” stands out to be the critical capabilities. EW self protection systems - not be defined as payloads, and are more close to be defined as survivability systems - utilize technologies having big commonalities as that of the EW mission payloads but poses more constraints to the main mission equipment in terms of size, weight, power and electromagnetic compatibility requirements.

UAV Payload Technological Trends

Synthetic Aperture Radar (SAR), capable of operation in day, night and even adverse weather conditions remains as the superior payload for Surveillance and Reconnaissance missions, especially in areas with cloud coverage. The integration of Inverse SAR mode enables to generate images of even slowly moving targets, valuable for identification of ships. Interferomeric SAR mode is also challenging that allows accurate measurement of terrain elevation and target height. Foliage Penetration capable SAR systems enable detection of military vehicles hidden under trees. The polarization information has leaded a new technology of polarimetric SAR which is a considerable current interest. Polarimetric SAR data contain information on scattering mechanisms by different objects’ structure and material, and as such, they can be used to distinguish the scattering objects and to improve image classification. Additionally, Ground Moving Target Indicator (GMTI) mode displays moving targets as an additional information layer on SAR image. UAV SAR payloads also tend to cover Air Moving Target Indicator (AMTI) mode in addition to GMTI.

SAR payloads mostly operate in strip-map mode for wide area coverage and spot-light mode for image generation of particular targets. Typical UAV SAR payloads operate at X (8-12 GHz) or Ku (12-18 GHz) bands to keep dimensions compatible with UAV platforms **[Ouchi, 2013]**. Technological tendencies enable the development of ultra light-weight SAR payloads operating up to Ka band (26,5 – 40 GHz). Remembering the short range of the millimeter wave payloads, this type of payloads may have potential application for close-in UAVs.

Table 3 indicates some of the SAR payloads, as compiled from military defense web sites (www.af.mil, www.airforce-technology.com, www.army-technology.com and www.defence-update.com)

Platform	***Payload***	***UAV Manufacturer***	***Payload Manufacturer***	***Band***	***Resolution (m)***
Global Hawk	Integrated Sensor Suite Radar	Northrop Grumman/USA	Raytheon/USA	X	<1,8
Heron	EL/M-2055	IAI/Israel	ELTA/Israel	**Unknown**	<1
I-GNAT	LYNX	General Atomics/USA	Sandia Lab/USA	Ku	<0,1
LUNA	MISAR	EMT/Germany	EADS/Germany	Ka	<0,3
RQ-1 Predator	AN/ZPQ-1TESAR	General Atomics	Northrop Grumman/USA	Ku	0,3 – 1
RQ-7A Shadow	MiniSAR	AAI Corporation/USA	TNO Lab/Netherlands	Ka, Ku, X	<0,5
Watchkeeper	I-MASTER	UAV Tactical Systems/UK	Thales/France	Ku	<1
S100 Camcopter		Schiebel/Austria			

Table 3: UAV SAR Payloads

No single metric can fully describe the performance of any payload; but the main parameter characterizing the SAR payload is the range resolution of the imagery and it is determined mainly by the radar instantaneous bandwidth. As a rule of thumb; 500 MegaHertz instantaneous bandwidth corresponds to approximately 0,3 meters range resolution. Super resolution processing and algorithms are focused topics for increasing the image resolution.

Electro-optical/infrared (EO/IR) cameras have been the widely used payloads for Surveillance and Reconnaissance missions as they provide the highest-quality imagery than the other payloads which is so important for target recognition and identification. EO/IR cameras can be analyzed in two categories; those that rely on reflected light (visible, near, and short wave IR, 350 nm – 2.5 microns wavelength) and those that rely on imaging the thermal emissions of the object itself (3- 14 microns wavelength). Cameras working in the visible and near IR use Silicon based devices, near short wave IR cameras use Indium Gallium Arsenide (InGaAs), and thermal IR imagers use Mercury Cadmium Tellur (MCT) and Indium Antimonide (InSb). The main parameters defining the EO/IR camera performance are; pixel size (the actual area that is sensitive to light), cell size (the spacing of pixels in the imager), number of pixels (horizontal and vertical), Signal Transfer Function (SiTF), Modulation Transfer Function (MTF), responsivity and linearity, noise and spectral sensitivity **[Fantone, Imrie and Zhang, 2009]**. It is beyond the scope of this paper to define these parameters and their effect on the image resolution; interested readers can refer to **[Fantone, Imrie and Zhang, 2009]** or more comprehensively to **[Shumaker, Accetta and Campana, 1993]** for details.

IR focal plane array technology tends to enable higher pixel arrays that eventually promise imagery with higher quality. Image processing in multi-spectral (10 spectral channels), hyper-spectral (100 spectral channels), and ultra-spectral (1000 spectral channels) bands offer expanded capabilities to counter camouflage, concealment, and foliage penetration **[Kitowski, 2003]**.

Besides the EO/IR cameras being used as payloads for Surveillance and Reconnaissance missions, laser systems capable of spotting, designating and ranging are widely used for guidance function of UAVs with Strike mission.

The parameters characterizing radar electronic intelligence and radar electronic support systems payload can be summarized as; a very wide frequency range coverage (1/2 to 18 GHz); sensitivity (-50 to -110dBmi), antenna gain (-5 to +25dBi), frequency measurement accuracy (50Hz to 10MHz), time-of-arrival measurement accuracy (1ns to 1ms), angle-of-arrival measurement accuracy (0,1° to 10°) and pulse density (100k to 10Mpulses/s) **[Smestad, Øhra, and Knapskog, 2000].**

Various type of antennas are candidates for radar, radar electronic support, radar electronic attack, communications electronic support, communications electronic attack, electronic intelligence, communications intelligence and communications relay payloads; the widely used are the dishes and the blades. However the technological trend is moving towards conformal antenna arrays, in which the aircraft fuselage, nose and/or wing functions as an antenna providing higher gain; that is expected to overcome mass and drag constraints. Figure 3 indicates a Ku-band conformal array to be used at the nose part of a mini UAV **[Malmqvist, Samuelsson and et.al, 2007].**

Figure 3: Photo of a Ku band conformal antenna array

Receiver types to be used in radar electronic intelligence, radar electronic support and radar electronic attack are super-heterodyne receiver, instantaneous frequency measurement receiver, channelized receiver and digital receiver. Design and development of receivers with high sensitivity, wide bandwidth and precise parameter measurement are the main technological challenges. However; wide band and high sensitivity requirements are generally contradictory and this problem tends to be overcome by use of multiple receiver structures as required by the operational requirements. For example, an instantaneous frequency measurement receiver having wide instantaneous analysis bandwidth but poor sensitivity and poor parameter measurement accuracy can be used with a digital receiver having relatively lower instantaneous analysis bandwidth but higher sensitivity and better parameter measurement accuracy. The constraint for the digital receiver is mainly due to the limited sampling rate of current Analog to Digital Converters (ADCs) **[Tsui, 1995]**. ADCs with higher sampling rate will overcome the digital receiver performance constraints, in the future.

Extended computational power and miniaturization of the processor systems are the evolving technologies, serving to all UAV payloads. Often graphic processing units, GPUs, are widely used for data processing. For applications with strictly constrained space and power requirements, multi-core processor systems embedded in Field Programmable Gate Arrays is becoming charming **[Schleuniger, Kusk and et.al, 2013].** Figure 4 indicates performance analysis of GPUs as compared to single processor structures **[Gupta and Babu, 2011].**

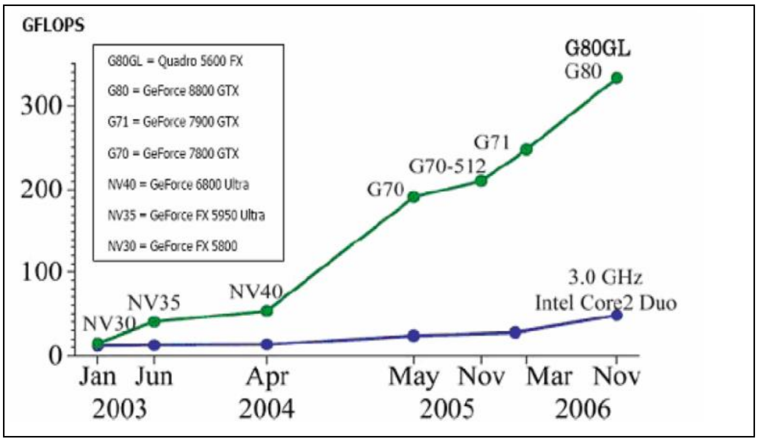

Figure 4: Floating-point operations on CPU and GPU

SIGINT and EW missions are critical in military information chain and payloads for these missions needs to operate in very dense signal environments. Therefore signal detection, classification and identification algorithms in dense environment are topics to be worked on.

Parameters defining the performance of the electronic attack payload may vary concerning if the jamming is to be executed in stand in i.e. the UAV carrying the jammer is between the shielded vehicle and the threat radar or stand off i.e. the shielded vehicle is closer to the threat radar than the jamming platform. However for each; operating frequency and effective radiated power can be accepted as the main parameters defining performance of the radar electronic attack payloads. Design and development of wide bandwidth, high power amplifiers with high efficiency is a major technological trend. Additionally for the generation of coherent jamming techniques the use of Digital Radio Frequency Memory (DRFM) is required. Wideband DRFM embedded with the receiver provides fast response time and the integration of jamming technique generator, DRFM and digital receiver in a compact structure is a critical technology.

As the SEAD and radar self protection systems have similar building blocks as that of the Radar EW payload, the technological tendencies of the former as explained above similarly apply to that of the later.

Research on Communications Relay payloads tends towards software defined radios, which intended to implement a broader range of capabilities as compared to the hardware radios, through elements that are software configurable. Software defined radio provide software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (such as hopping), and waveform requirements of current and evolving standards over a broad frequency range **[Tribble, 2008].**These flexibilities are provided by the use of multiple waveforms to be designed to run on a single hardware which can be reconfigured at different times to host different waveforms depending on the operational needs. Hence most of the research regarding the software defined radio resides on the design of complex waveforms and configurable Radio Frequency front end structures.

Radar and EW payload designs tend to have some additional conceptual implementations. One payload having the same frequency band of operation can be used to handle multiple missions in order to have an effective size and weight budget. There exists ongoing research for the development of radar payloads that perform Surveillance and Reconnaissance and Communications Relay missions on a time shared basis. A typical example is a radar payload operating in Frequency Modulated Continuous Wave mode to perform Surveillance and Reconnaissance and Communications Relay missions on a time shared basis **[Barrenechea, Elferink and Janssen, 2007].** Combining SAR and radar electronic support system functions on the same payload is another research area. Such payloads are being defined as "Multifunction RF payload" and seem as a conceptual evolution for the miniaturization of the UAVs **[Huizing, 2009].** For the "Multifunction RF payload" cases the main challenge will be the design of reconfigurable Radio Frequency front end architectures in order to instantaneously reconfigure the array to the required functions and parameters. Also the multi octave wide band Transmit/Receive modules and beam forming is a topic research goes on for "Multifunction RF payload" **[Lacomme, 2003].**

Furthermore, as a new conceptual implementation; the tasks to perform the UAV mission can be distributed between the "payload" and "platform sensor systems"; for example same UAV radar may be used as "payload" for target detection and also as "sensor system" for "sense and avoid" **[Kitowski, 2003]**. Sense and avoid systems, collect data about the air space, determines if the data indicate a collision in the near future and calculate an action to avoid the collision. With these functions, not only radar systems, but also electro-optical systems and laser range finders can be candidates for sense and avoid system solutions. For these cases the challenge will be on resource allocation and resource control algorithms; aiming at what time the related mission will be applied with which resources.

Another paradigm shift is from platform centric operations in which each platform relies upon its own payload data to network centric operations, in which information is produced from data provided by more platforms. This concept is highly interrelated with the payload technologies. As the Australian Defense Science and Technology Organization research has concluded the geo-location data produced from the direction of arrival data obtained from eight UAV platforms with payload of 5 degrees RMS direction finding accuracy has around 50% less error than the one produced from the direction of arrival data obtained from two UAV platforms with payloads of 0.5 degrees RMS direction finding accuracy **[Finn, Brown and Lindsay, 2002].** For such cases, even not directly related to the payload, "cooperative control" i.e., the control of multiple UAVs in a coordinated fashion shall stand out as a challenging problem.

UAV PAYLOAD DESIGN and DEVELOPMENT ACTIVITIES at ASELSAN REHIS DIVISION

ASELSAN REHIS Division has developed and manufactured UAV Synthetic Aperture Radar (SAR) System capable of acquiring real-time images with strip-map and spot-light modes and detecting ground moving targets with Ground Moving Target Indicator (GMTI) mode at up to 30.000 feet altitude at long ranges. The state-of-the art multi channel antenna enables SAR imaging and the GMTI modes to be executed on the same antenna, and also allows for low speed moving target identification. The SAR System has been designed and developed to enable radar imaging and moving target detection under all weather conditions even in cloudy and rainy weather during day and night. The system has a slotted waveguide antenna mounted at a gimbaled structure as seen in Figure 5. SAR System is compliant with military standards such as MIL-STD-810F and MIL-STD-461E. In addition, the system output data is compliant with NATO STANAG 7023 and 4607 formats. In addition to strip-map, spot-light and GMTI modes, currently algorithm and software development efforts are on additional ISAR and Naval Search modes. Due to its 360^o antenna rotation capability, search mode will have a 360^o field of view.

Figure 5: ASELSAN SAR and Image taken by ASELSAN SAR

ASELSAN SAR development process is defined in Figure 6.

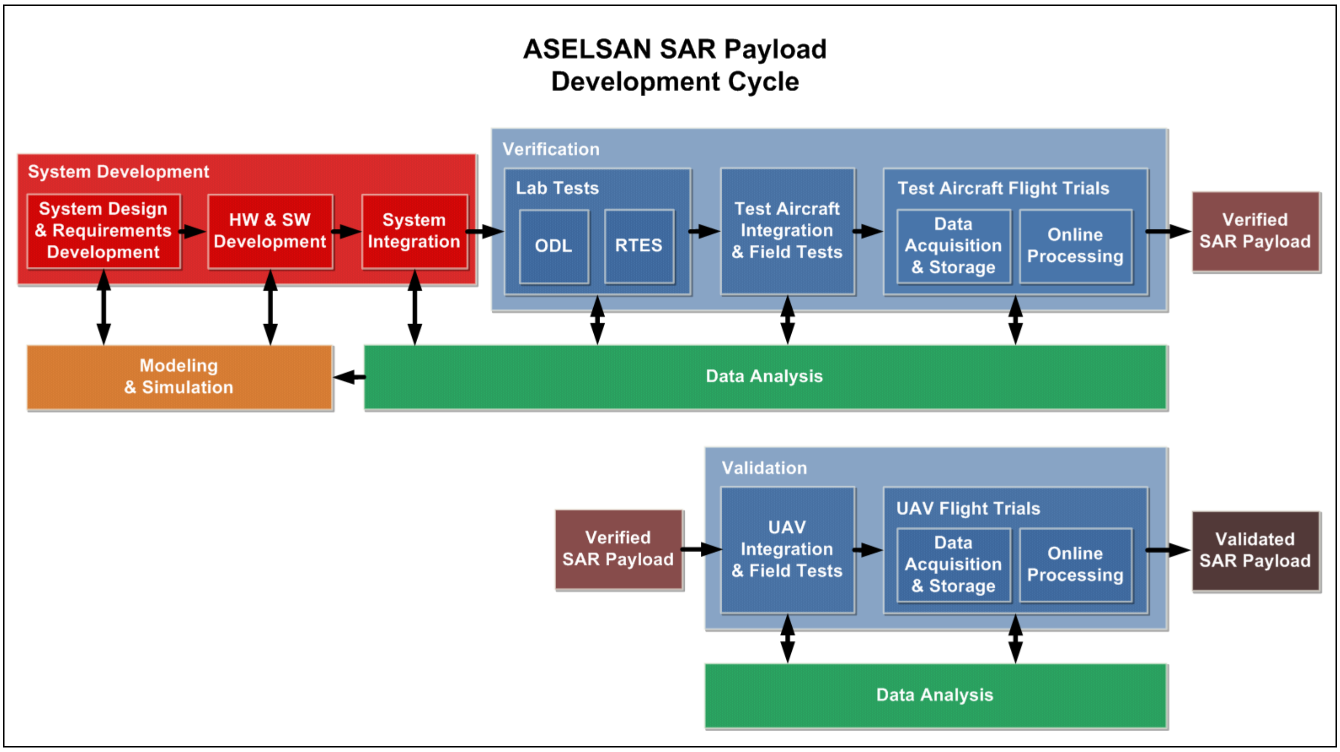

Figure 6: ASELSAN SAR Payload Development Cycle

ASELSAN REHIS Division's product portfolio also includes operational SIGINT, EW, SEAD system system payloads for manned aircraft as seen in Figure 7. Current efforts are stil on development of architectures to integrate these EW capabilities into UAVs.

(a) (b) (c)

Figure 7: ASELSAN EW Payload System Units:
(a) Integrated DRFM Technique Generator, Digital Receiver (b) Fast Beam Steering Phased Array Transmitter/Receiver Structure (c) Central Processing Unit

Wide and narrow band digital receivers, DRFM based technique generators, solid state power amplifiers, active electronic scanning array transmitters and antennas, together with the serial production capability of microwave modules are the strength of ASELSAN's new generation EW systems. Investments in the enabling technologies together with the know-how and expertise in EW system design resulted in state-of-the-art products. Re-packaging and optimizing the existing building blocks according to requirements of UAVs will be the next step towards more compact solutions.

CONCLUSION

UAVs have a growing missions and tend to have great role to play in dangerous, dirty, dull operations. Payloads have a mission critical role in UAV operational performance. The technology is evolving to have smaller, ligher weight and less power consuming payloads.

In order to have such payloads, not only technologies related to the UAV payload elements i.e.; for antenna, receiver, processor, transmitter are evolving, but also new operational concepts are being developed to utilize weight and power budget more efficiently. The future will put even more focus on size, weight and power and also on generation of new concepts.

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