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Application of integrated EFIS-EMS,[i] NAV-COM[ii] and automated on-board systems in GAT[iii] light aircraft sector considering weight reduction requirements

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The cockpit design philosophy of light aircraft has been changed because the high developed up-to-date digital on-board system applications support the flight, the navigation and the engine parameters are integrated and monitor simultaneously. Evidently, the biggest advantage of the on-board integration is save weight because only one data box is enough to install into the panel without many separated instruments. In addition, the on-board system can be automated and combined EFIS-EMS and NAV-COM functions the result is unambiguous to increase the flight safety in GAT sector.

Introduction

This article is focusing on up-to date on-board aircraft systems, on their use to increase flight safety in relation GAT, which is popular and advanced in XXIst century. Today whoever can observe the growing tendency of use of small and light aircraft, furthermore analyzing some prognosis, the numbers of GAT aircrafts will probably be doubled in the future compared the number we have now all over the world. Small aircrafts used daily will be as normal for next generation like cars are applied in our life today. As follows, a new, modern philosophy must be introduced in the aircraft design and manufacturing procedures according as applied and operative regulations. On the one hand, really important consideration is the arrangement of cockpit, which must be simple. On the other hand up-to date digital instrument integration is basic requirement. The design of the cockpit should consider all aspect of ergonomy; human friendly flight environment creation is one of the main goals. Substantial point is that the civil and military flights can be coordinated flexible in same time; the quick identification and the accuracy of separation are significant questions.

[i] EFIS-EMS: electronic flight information system, engine monitoring system
[ii] NAV-COM: navigation and communication systems
[iii] GAT: general aviation terminal

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In my article some applications, as integrated EFIS-EMS, NAV-COM and automatized on-board flight control systems are to be presented, these are standard solutions of serial produced UL,[iii] LSA,[iv] VLA[v] aircrafts (Fig. 1), which are made by Corvus Aircraft Kft in Hungary. The goal of my description is to present the new, modern cockpit design in general light aircraft sector considering weight reduction of the aircraft. I am presenting my common experience about integrated on-board system applications and analyzing the advantage of new philosophy and disadvantage of the second and third generation cockpit solutions.

Fig. 1. Corvus CA-21 Phantom

Some problems of GAT flights

A general tendency is that in non-controlled airspaces, where the GAT and non-commercial flights are completed in conditions VFR,[vi] in VMC[vii] transponders are very often inactivated. According to ICAO[viii] rules as G-class free airspace is provided for that kind of flight, and this airspace can be used by any planes. The G-class airspace is limited by borders in horizontal, upper and lower limits in vertical, no traffic coordination is available, only flight information service is activated, it is one of reason why called non-controlled airspace. The G-class airspace is defined in Hungary from

[iii] UL: ultra light aircraft with maximum take-off mass 472.5 kg
[iv] LSA: light sport aircraft with maximum take-off mass 600 kg
[v] VLA: very light aircraft with maximum take-off mass 750 kg
[vi] VFR: visual flight rules
[vii] VMC: visual meteorology conditions
[viii] ICAO: International Civil Aviation Organization

ground level to AMSL[ix] 9500 feet. All area of the country is masked but some part is subtracted, these are functional as a controlled airspace, i.e. TMA,[x] MTMA,[xi] TRA.[xii]

One common daily problem is when light aircraft having no flight plane accidentally crosses controlled airspaces and the coordinator information service does not have correct information about flight path. In that case, unidentified airplane, (albeit no ill-intentioned goal) follows this procedure very close to airport, the control service must reorganize and modify the departure and approach time of other aircrafts. This activation can generate higher risk for flight safety. For instance, in Hungary in last few years it happened many times that glide-sale parachutes crossed the Budapest TMA, where it is prohibited. Furthermore, standard problem, when ultra light aircraft flies, and they proceed direct into military TRA sectors.

Due to fast development of digital electronics, small aircraft could be equipped integrated on-board flight and navigation modules, which systems particularly facilitate the flight safety for example sending an alert message to the pilots in case they crosses prohibited, dangerous or military area. Advantage of the use of integrated EFIS-EMS and NAV-COM systems is that they support night and instrument flight activities.

Past, present and future in GAT on-board systems – tendencies of development

On-board flight systems in 1970 and 1980

The typical example of the second generation on-board system is the CESSNA 150,152,172,182 aircraft series. Such general on-board system environment is shown on Fig. 2, where cockpit instruments of a CESSNA 172 N model are presented. The flight, navigation and engine condition monitoring instruments are separated and we cannot define integrated on-board systems and instruments. The flight and engine condition monitoring instruments are controlled by mechanical analogue method, the NAV and COM systems powered electrically. The navigation instruments cannot create inertial contact by the external GPS[xiii] equipment.

[ix] AMSL: altitude mean sea level
[x] TMA: Terminal Control Area
[xi] MTMA: Military Terminal Control Area
[xii] TRA: Terminal Restricted Area
[xiii] GPS: global positioning system

Fig. 2. Individual instruments in CESSNA 172 N/1976

In the Table 1 the functionality of the on-board flight instruments and systems has been summarized. We can ascertain also on the Fig. 2 that all instruments are separated and no integrated hardware application is available.

Table 1. Individual instruments (summary)

Instrument	System	Functionality
airspeed indicator ASI	pitot-static	flight condition check
altimeterALT	static	flight condition check
variometer VARIO	static	flight condition check
attitude director	vacuum	flight condition check
turn coordinator	gyroscope	flight condition check
slip indicator	centripetal force	flight condition check
on-board compass	vacuum	navigation check
magnetic compass	magnetic property	navigation check
NAV system (VOR,[xiv] ADF,[xv] ILS[xvi])	electric	navigation check
COMM system (radio, transponder)	electric	navigation check
engine state conditions (CHT,[xvii] EGT,[xviii] oil pressure, oil temperature, fuel quantity, tach)	electric	engine state conditions

[xiv] VOR: VHF omni directional range
[xv] ADF: automatic radio direction finder
[xvi] ILS: instrumnet landing system
[xvii] CHT: cylinder head temperature
[xviii] EGT: exhaust gas temperature

Nowadays, requirements of on-board system applications

Due to the highly developed informatics and computer applications the fifth generation on-board system integration is used and GAT pilots can fly in digital environment.

The main advantage of the integrated systems is that they can operate many conventional functions of sending and displaying parameters via digital data bus. The Fig. 3 shows the cockpit of Corvus CA-21 Phantom in glass-cockpit arrangement. The main instrument is the Dynon FlightDEK-D180 integrated EFIS-EMS on-board module, (6). The main purpose of this instrument is to display the flight and engine data simultaneously. The integrated NAV-COM system (19) is able to collaborate with external GPS (11 on the Fig. 3), and available function is that the GPS and NAV data can be transferred directly into the Dynon central panel. Of course, we cannot be avoided that the general mechanical analogue instruments in the cockpit (no. 8 on Figure 3), but these functions are only back-up ones. In that case, some problems appear in electrical network pilot must use four most important instruments as horizontal airspeed indicator, vertical speed indicator, altimeter, and magnetic compass.

Fig. 3. Integrated on-board system Corvus CA-21 Phantom cockpit

On-board EFIS and EMS systems – Dynon FlightDEK-D180 flight computer on Corvus models

The Dynon FlightDEK-D180 Electronic Flight Information System is a modular appliance, displaying all flight condition information (see details on Fig. 4.) on the central monitor panel. On the background, the actual flight position of the airplane is indicated as attitude director, turn coordinator, slip indicator. Besides this, any other significant flight information like altitude, airspeed, vertical speed indicator climb or descent ratio, heading bag, wind direction and speed, outside temperature, angle of attack and autopilot condition also can be displayed. The EFIS block is linked with many sub-systems and with a central computer gathering data and computing the reference values. The heart of the EFIS is the ADAHRS (Air Data Attitude and Heading Reference System) internal module, supported by external reference sensors. On the Fig. 5 shown the ADAHRS and aircraft reference systems and the Table 2 contains the integrated modular pattern elements. (The numbers in Table 2, are in coherence with another numbers, assigned on Fig. 5).

The Dynon system is supplied by main electrical system of the aircraft, for external power 10–30V DC is necessary. In case, when there is no available external power, the Dynon switches to internal back-up battery, providing 13–17V DC and maintains this state for minimum 1.5 hours.

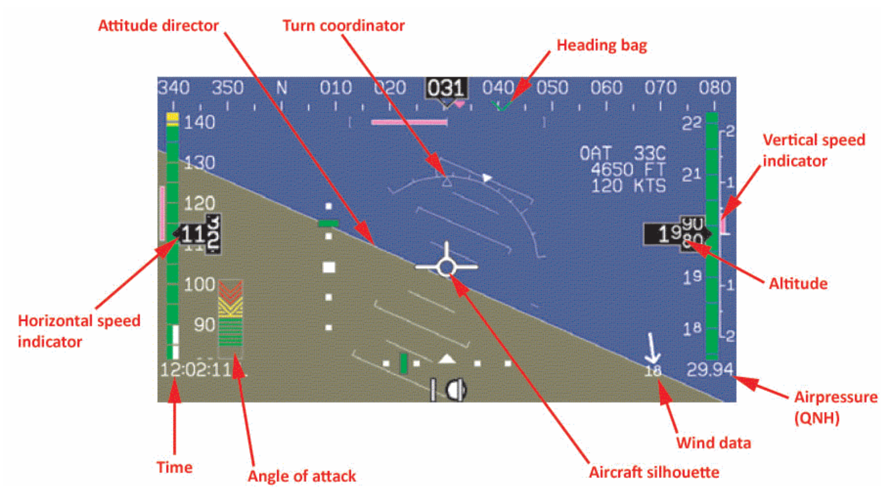

Fig. 4. Dynon FlightDEK-D180 EFIS displayed information

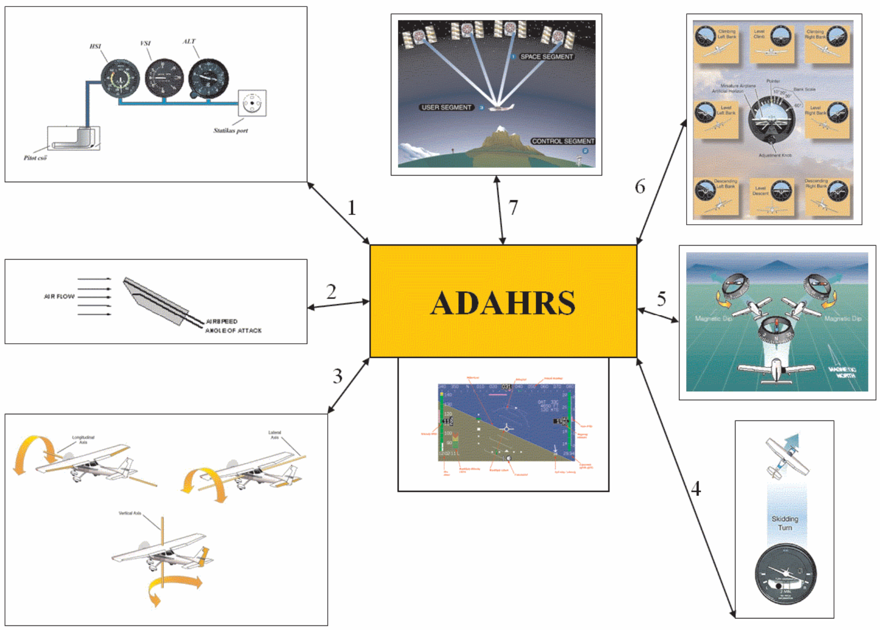

Fig. 5. The ADAHRS hardware reference

Table 2. The ADAHRS reference systems (reference numbers on Fig. 5)

Instrument, system	GPS	Pitot	Static	AOA[xix]	Magnetometer	Sensor	Accelerometer
vertical speed indicator			X-1				
horizontal speed indicator		X-1	X-1				
altitude			X-1				
angle of attack		X-1	X-1	X-2			
turn coordinator	X-7					X-3	X-3
heading	X-7				X-5	X-3	X-3
slip indicator							X-4
attitude indicator	X-7		X-1		X-5-6	X-3	X-3
air pressure QNH			X-1				
wind data						X-3	X-3
autopilot system	X-7	X-1	X-1	X-2	X-5-6	X-3	X-3

[xix] AOA: angle of attack

The Dynon FlightDEK-D180 is an integrated on-board computer and able to function as Engine Monitoring System (Fig. 6). The principle of work method of the EMS is similar to the EFIS. The central panel displays parameters of the engine as RPM,[xx] manifold pressure, oil temperature, oil pressure, and cylinder head temperature; exhaust gas temperature, fuel pressure, fuel quantity. The advantage of EMS arrangement is that all data are shown on one display. During flight, the EFIS and the EMS information can be displayed simultaneously on display.

It is really important fact that all EFIS and EMS info is integrated into one module and subsequently it is not necessary to built up self-contained instruments, and as a result – the weight of instrument panel decreases. Probably, it is the most significant consideration of design light aircrafts.

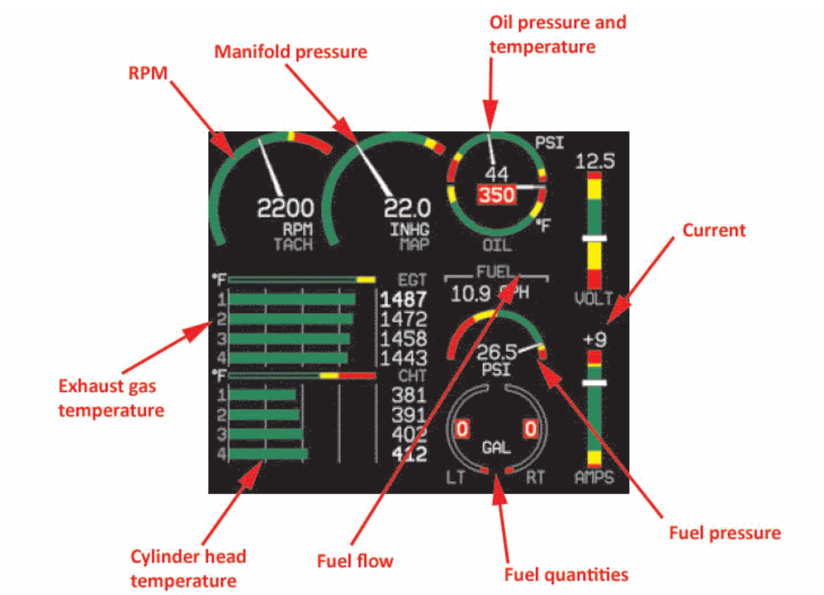

Fig. 6. Dynon FlightDEK-D180 EMS displayed information

[xx] RPM: revolution per minute

Applied NAV/COM/GPS system integration with the Dynon FlightDEK-D180 EFIS-EMS on-board computer on the Corvus planes

The Dynon FlightDEK-D180 equipment is able to communicate with NAV-COM on-board systems. This application supports the instrument navigation possibilities.

Obviously it is a fact, many GAT light categories aircraft are unable to fly in IMC,[xxi] because they are not equipped with anti-ice systems, double pitot-static systems. Without these elements the flight in IMC is not allowed. The idea of integrated EFIS-NAV-COM applicants is to endorse activities of the pilot. Dynon's EFIS-based instruments include an HSI[xxii] page whenever connected to a supported external navigation source. The horizontal situation indicator commonly called the HSI is an aircraft instrument normally mounted below the artificial horizon in place of a conventional directional gyro (DG). It provides an easily understood pictorial display and is one of the most popular navigation instruments ever devised. The HSI page offers a precise navigation tool to guide pilots throughout the enroute, terminal and approach phases of flight. It also reduces pilot workload and offers a cost-effective and space-saving alternative to traditional mechanical HSI or CDI instruments. In case, when the Dynon FlightDEK is integrated with external NAV or GPS, the HSI can be displayed on the on-board monitor, which is really effective indicator during navigation procedures. Primarily, the Dynon FlightDEK can be combined directly with GARMIN SL-30 NAV-COM and GARMIN GNS-430/530 GPS-NAV-COM systems, but of course many other similar standardized equipment also available to work together with the Dynon network. The HSI is able to operate in two modes; first combination is the HSI-NAV and the second is the HSI-GPS functions. If the data transport happens in HSI mode between Dynon and on-board NAV applications, it is able to indicate course direction, VOR info as OBS,[xxiii] NAV, DME,[xxiv] TO-FROM INDICATION, in addition if the navigation module is integrated with LOC[xxv] mode ILS[xxvi] and GLIDESLOPE approach information also can be indicated on the screen. The HSI operates together with the on-board GPS; in this case the course, vertical guidance, aberration, heading, ground speed; ground level and distance from waypoint are indicated. The Fig. 7 is presenting HSI screen in NAV mode and fig. 8 the HSI-GPS can be sight.

[xxi] IMC: instrument meteorology condition
[xxii] HSI: horizontal situation indicator
[xxiii] OBS: omni bearing selector
[xxiv] DME: distance measuring equipment
[xxv] LOC: localizer
[xxvi] ILS: instrument landing system

Fig. 7. HSI in NAV mode

Fig. 8. HSI in GPS mode

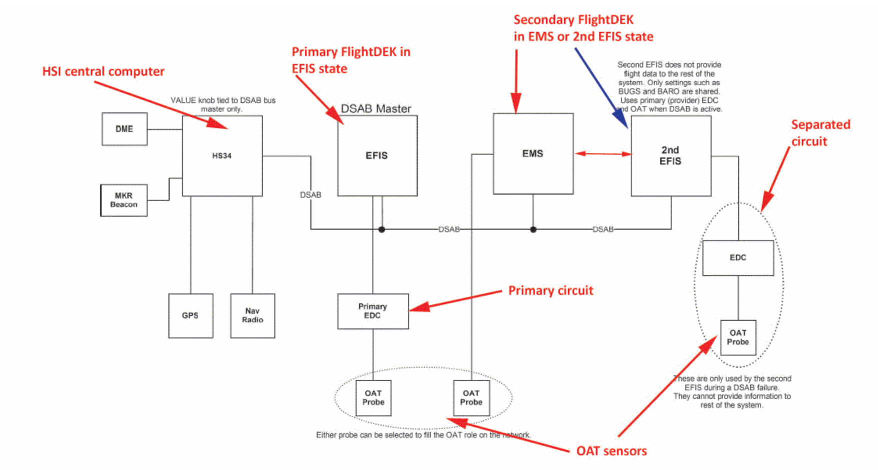

Fig. 9. Duplicated EFIS – EMS on-board system

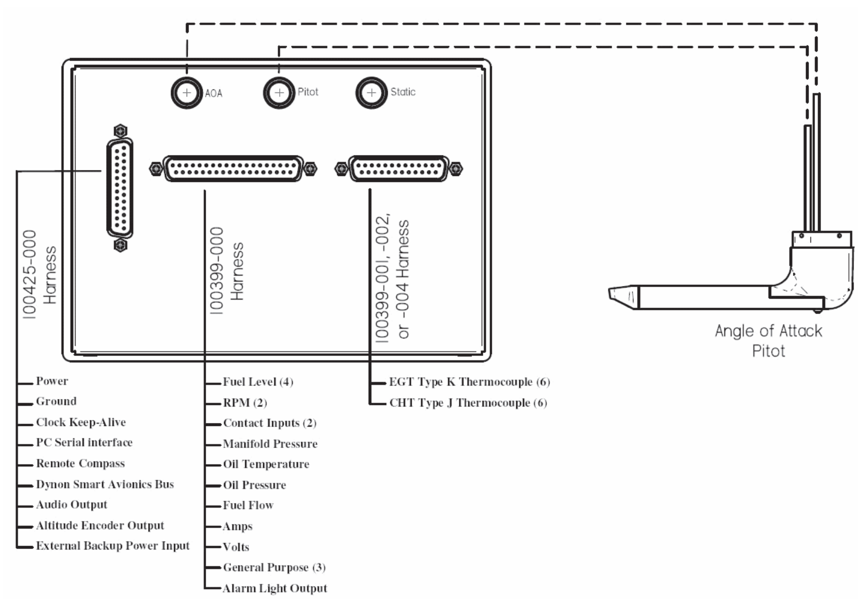

Fig. 10. Dynon FlightDEK D-180 connector plugs

The Dynon and NAV-COM-GPS systems communicate via an internal network, which is the DSAB.[xxvii] The preliminary function is the data transport of the DSAB, howbeit really significant, the DSAB can be used in duplicated mode called duplex state. In duplex mode two Dynon FlightDEK computers are on the board, one of them works in EFIS, another one in EMS mode. The biggest advantage of duplicated operations is that the EFIS and EMS functions are separated, the display resolution can be better, and information becomes much more readable. A duplicated system integration block diagram is shown on Fig. 9, where the main on-board FlightDEK computer is the DSAB Master EFIS, another FlightDEK operates in EMS mode and secondary function of this module is the back-up EFIS. The DSAB Master is electrified by primary EDC all other equipments are supplied with electric energy via the DSAB network. Two OAT sensors are integrated into one network. EFIS and EMS also have independent external sensors to increase flight safety. Howbeit, the second FlightDEK main function is the EMS it can be operated in back-up EFIS mode. As the consequence this on-board applicant has an external electric supply network with an OAT[xxviii] sensor. The HSI channel is wired directly onto the DSAB network and GPS, NAV, COM, DME, MARKERS are integrated with the HS34 HSI module. The HSI data comes from external panel mounted on portable navigation devices. These devices can either be interfaced to Dynon's EFIS or EMS systems via their single wire serial connection or through Dynon's optional HS34 HSI Expansion Module. The HS34 module expands the interface to include multiple connections to analogue, and serial signals to facilitate a larger variety of NAV radios and devices. On the Fig. 10 the outer connection plugs of Dynon FlightDEK are presented.

Automated flight control – autopilot – systems on Corvus models

There is a basic procedure in the commercial flight sector to combine the on-board systems with automated flight control (called autopilot) equipments. The Dynon FlightDEK-D180 computer in HSI mode provides collaboration possibilities with autopilot systems. The integrated EFIS and NAV-COM-GPS navigation module can be combined the Dynon AP (AP is autopilot) assemblies.

The operational base of the Dynon AP is a reference system, which are the HS34 HSI computer and the DSAB network. The Dynon AP is able to control the aircraft automatically around two – the roll and the pitch – axis. The Dynon AP can work in four main modes and fourteen sub-modes.

[xxvii] DSAB: Dynon smart avionics bus
[xxviii] OAT: outside temperature

The four main modes are:

1. AP status HDG[xxix] OFF/ALT OFF, – the pitch and roll control are switched off;
2. AP status HDG ON/ALT OFF, - the roll is activated and pitch is in off;
3. AP status HDG OFF/ALT ON, – the roll is inactive and pitch is activated;
4. AP status HDG ON/ALT ON, – both functions are activated.

The outside components of the Dynon AP are servos, wires and stop block elements, which must be built up into the aileron and elevator control mechanisms. The installation method and the location of parts depend on the control surface deflections, gear and transfer ratios and the control system pilot force. The most important aspect is the arising pilot force in the aileron and elevator system. Multiple servos models are available to suit different aircraft control force requirements, for instance from at 4 Nm of torque, to at 10 Nm of torque. The weights of servos are optimized, especially to light aircrafts requirements. A lightweight aluminium case houses a stainless steel gear train to decrease weight while not sacrificing strength. The servo control arm is captured by a castellated nut and secured by a cotter pin, just like other critical interfaces in the aircraft. Each servo is managed by its own microprocessor, making the servo an active, smart extension of the autopilot. This simplifies the control-surface-to-servo calibration, and prevents the servo from driving itself endlessly like other servos can. As an ultimate mechanical failsafe, a simple and effective shear pin is employed to let you break the servo free of the aircraft control surface in an emergency. In next, to concentrate how the roll and pitch modes can work, firstly about activated roll reference cases.

Roll modes:

1. HDG status, this is the HEADING activation, when the magnetic direction of the aircraft is in reference. The AP communicates with the Dynon EFIS heading bag;
2. TRK[xxx] status, this is the TRACK activation, when the GPS ground track is in reference. The AP communicates with the integrated GPS system;
3. 180° status, this is a special mode, when the aircraft makes a 180° turn back, oppositely the defined flight direction;
4. NAV GPS status, when the reference data coming from the GPS. The AP is able to maintain the flight path to the predefined GPS coordinates, in addition considering wind traverse deviatory effects;
5. NAV VOR status, when the reference point is a VOR station’s radial;
6. NAV LOC status, when the reference point is a LOC station and ILS approach can be made with this method.

[xxix] HDG: heading
[xxx] TRK: track

Pitch modes:

1. ALT MAX AIRSPEED status, when the AOA of plane is controlled as the predefined airspeed can be reached but never had been in overstepped. As follows the pitch, elevator deflection is governed;
2. ALT MIN AIRSPEED status, when everything happens out of accordance beforehand analyzed procedure.

Of course, all presented modes will be combined and pitch and roll modes can be active in same time. On Fig. 11 an installed model is presented, the servo is fixed to the wing rib; the control arm joins to aileron hinge and mechanical input arm of digital transmission of servo.

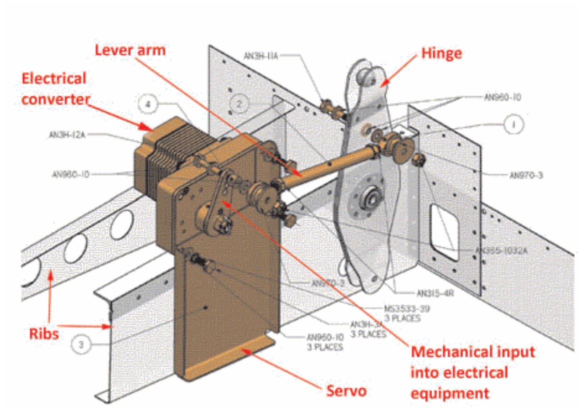

Fig. 11. Example to installed servo in aileron control system

Conclusions

I have experienced that today in aviation industry sector the development and research activities concentrate on digital electronic, intelligent automated sub-systems and weight reduction solutions. Today, the questions are to produce the construction from light weight but high strength materials, subsequently once save weight, the fuel consumption can be less, alternative power-driven systems, environment-friend base materials and full-automated on-board systems can be applied.

All aircraft fabricants must modify the manufacture philosophy and apply new on-board integrated automatic systems without traditional cockpit instruments. There is only one possibility to consolidate raison d'être on the market because the number of aircraft in the airspace will be increased in the future than we can see now. The safe navigation and the exact quick identification are impossible without modern electronic systems. This trend is actual requirement both in civil and military sectors.

My viewpoint is we do not have to wait long time that the on-board system's configuration of light and small aircraft will be absolutely same as civil heavy passenger and military cargo aircraft. Flight by light planes will be automatic procedures, which do not depend on the meteorological conditions and other more factors.

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