U.S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY FLIGHT CONTROL PROGRAMS - PAST, PRESENT, AND FUTURE

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The U. S. Army Signal Corps is responsible for the research and development of electronic flight aids for Army Aviation. In connection with this activity the Signal Research and Development Laboratory has been actively engaged in providing engineering support in the field of automatic flight control systems for Army aircraft.

The initial needs for flight control equipment for immediate army applications were urgent; the Laboratory, therefore, evaluated a number of existent military and commercial autopilots for army fixed and rotary wing aircraft. Thus, several interim army flight control systems were generated. These systems ranged from a modified F-5 fixed wing autopilot to a U. S. Navy helicopter stabilization system. As new tactical concepts developed, the scope of Army aviation missions expanded, and the need for larger quantities and varied types of more advanced flight control systems became evident. The Signal Research and Development Laboratory recognized these needs and considered the problems that would be associated with the procurement, supply, and maintenance of these equipments. Thus, in early 1956, a study was begun to determine the feasibility of the development of a universally adaptable type of autopilot.

The objectives of this study were to determine the feasibility of the development of a set of modular components which when combined in various configurations would provide a variety of types of flight control systems. These systems would be readily adaptable to present and foreseeable Army fixed and rotary wing aircraft. Fixed wing and helicopter autopilot requirement study programs were initiated. The studies evolved a set of normalized autopilot system parameters for helicopters and fixed wing aircraft. Technical requirements were then generated for the development of an adaptable set of lightweight autopilot components. This concept which was nicknamed the " Universal Autopilot" received final task approval in 1957 and early 1958, the design of the " Universal Autopilot" by the Sperry Phoenix Company under the cognizance of the U. S. Army Signal Research and Development Laboratory was begun. This system as such is not a self adaptive autopilot since it possesses no gain changing features; it achieves adaptability through its mechanization (i.e., the method of combining the modular parts). The equipment is adapted to each aircraft's flight characteristics by means of plug-in calibration cards. It is obvious that this type of system does not obviate the need for aircraft aerodynamic information. However, this equipment is intended for use in relatively low performance fixed and rotary wing aircraft. These aircraft do not exhibit extensive aerodynamic changes in flight and therefore flight control systems with elaborate gain scheduling provisions are not required.

Figure 1 depicts each of the basic components of the " Universal Autopilot" . Note the absence of a centralized amplifier computer. The number of components shown in this figure are those which are required to form either a complete 5-axis helicopter displacement system with control stick steering or a 3-axis fixed wing displacement system. The legend denotes those units which are common to both types of system (HF), and those which are required only for the fixed wing (F), or rotary wing systems (H). Note the relatively low weights which are projected for these systems.

The control panel provides the necessary autopilot engagement switches and attitude synchronizers. The navigational coupler provides all the necessary circuitry to enable the coupling of various navigational systems (ILS, VOR, doppler navigator, etc) to the autopilot. The components under the sensor column of Figure 1 (i.e. vertical gyro, force link, accelerometer, etc) provide aircraft attitude, altitude, and pilot stick force sensing functions that are required to effect the various control modes. The power unit is a self contained servo-loop. It provides all those computing, amplifying, and prime mover functions which are required for a single flight control axis.

Thus, it can be seen that a variety of control systems can be readily mechanized by the combination of the appropriate number of sensors and power units (i.e. a single axis damper to a five axis helicopter displacement autopilot). Figure 2 illustrates a typical application of this equipment as a 3-axis displacement system in an aircraft.

A unique mechanization technique enables the use of the power unit (illustrated in the fixed wing system form) as a differential series actuator for helicopter applications. This is achieved by removing the power unit's capstan and interconnecting a flexible shaft to the differential linkage (illustrated in Figure 1). The differential linkage is installed in series with the existing helicopter push rods forward of the helicopter hydraulic power boost. It is essentially an irreversible screw jack mechanism which transforms the rotary motion of the power units to linear motion. Thus by means of this technique the autopilot signals are mixed differentially with all pilot cyclic stick inputs and are not reflected back to the pilot's stick.

The equipment described is intended for application in the present Army fixed and rotary wing aircraft, and foreseeable low performance Army vehicles. It is still in the equipment design and fabrication stages of development and may be subject to some minor modifications. It is recognized that this system cannot cope with the problems associated with higher performance aircraft which require high power irreversible hydraulic servos, and gain scheduling provisions.

The desirability of achieving self adaptivity of the equipment to each aircraft without requiring the necessity of developing gain scheduling computers dependent upon extensive aerodynamic information is an obvious objective. Thus, the need arises for the development of a sound adaptive technique. It is envisioned that the universality concept can be extended by the development of a modular adaptive controller and associated specialized sensors. If we imagine that Figure 2 represents a hypothetical VTOL installation (assume control stick steering is incorporated and the maneuver controller is deleted), it is obvious that the adaptive controller would be inserted downstream of the couplers, sensors, and control panel. It would provide all the necessary automatic adapting which would be necessary for this type of aircraft. The use of this controller in all aircraft applications in place of the calibration cards now being used would simplify flight calibration and logistic supply problems. However, this consideration must be weighed by equipment reliability considerations and equipment cost, weight, and size.

The Signal Research and Development Laboratory is preparing a technical requirement for the development of such a controller. It is anticipated that development of the adaptive controller will be initiated in the near future.

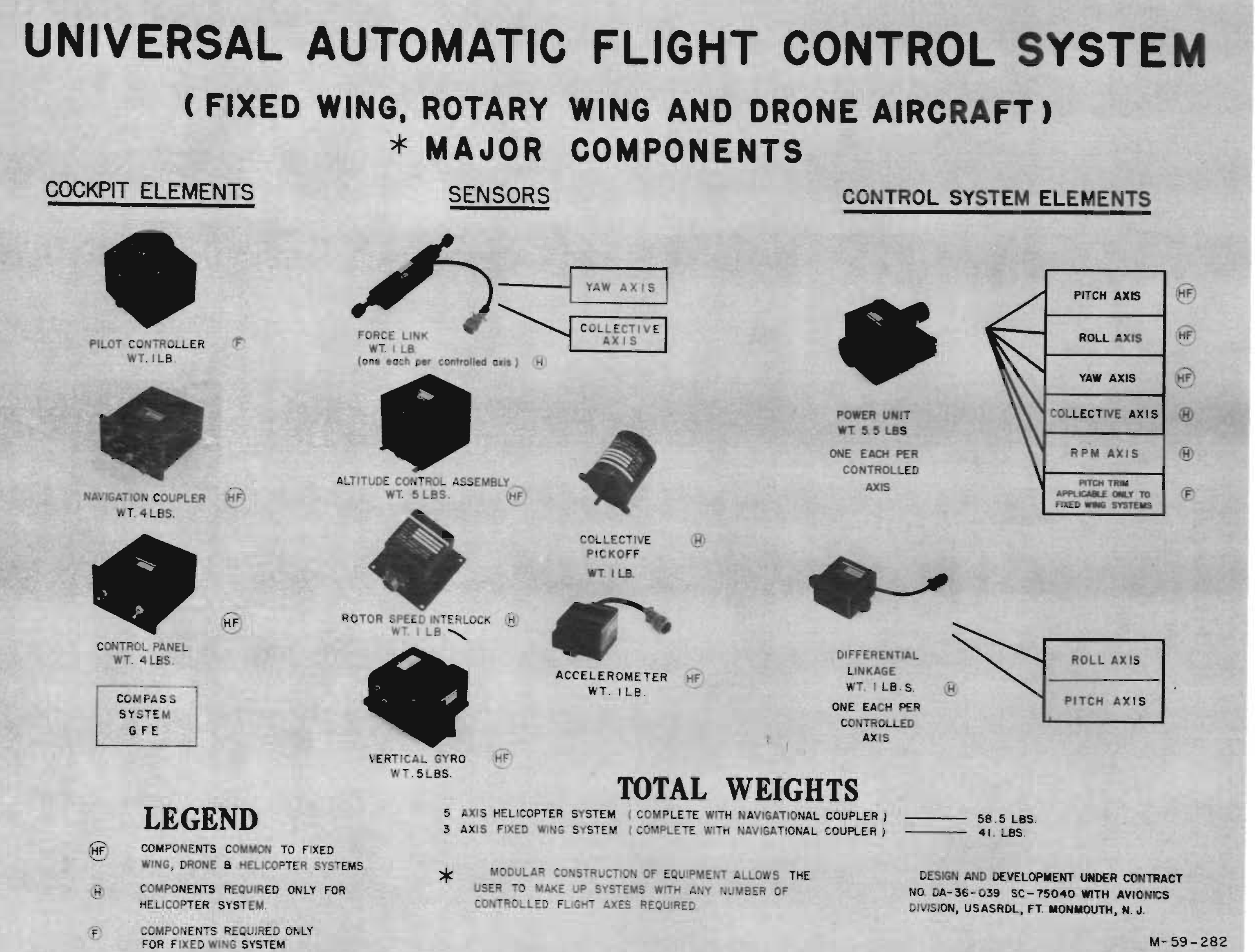
UNIVERSAL AUTOMATIC FLIGHT CONTROL SYSTEM
(FIXED WING, ROTARY WING AND DRONE AIRCRAFT)
* MAJOR COMPONENTS
COCKPIT ELEMENTS
PILOT CONTROLLER WT. 1LB (F)
NAVIGATION COUPLER WT. 4 LBS. (HF)
CONTROL PANEL WT. 4 LBS. (HF)
COMPASS SYSTEM GFE
SENSORS
FORCE LINK WT. 1 LB (one each per controlled axis) (H)
YAW AXIS
COLLECTIVE AXIS
ALTITUDE CONTROL ASSEMBLY WT. 5 LBS. (HF)
ROTOR SPEED INTERLOCK WT. 1 LB (H)
VERTICAL GYRO WT. 5 LBS. (HF)
COLLECTIVE PICKOFF WT. 1 LB. (H)
ACCELEROMETER WT. 1 LB. (HF)
CONTROL SYSTEM ELEMENTS
POWER UNIT WT. 5.5 LBS
ONE EACH PER CONTROLLED AXIS
PITCH AXIS (HF)
ROLL AXIS (HF)
YAW AXIS (HF)
COLLECTIVE AXIS (H)
RPM AXIS (H)
PITCH TRIM APPLICABLE ONLY TO FIXED WING SYSTEMS (F)
DIFFERENTIAL LINKAGE WT. 1 LB. S. (H)
ONE EACH PER CONTROLLED AXIS
ROLL AXIS
PITCH AXIS
TOTAL WEIGHTS
5 AXIS HELICOPTER SYSTEM (COMPLETE WITH NAVIGATIONAL COUPLER) —— 58.5 LBS.
3 AXIS FIXED WING SYSTEM (COMPLETE WITH NAVIGATIONAL COUPLER) —— 41. LBS.
LEGEND
(HF) COMPONENTS COMMON TO FIXED WING, DRONE & HELICOPTER SYSTEMS
(H) COMPONENTS REQUIRED ONLY FOR HELICOPTER SYSTEM.
(F) COMPONENTS REQUIRED ONLY FOR FIXED WING SYSTEM
* MODULAR CONSTRUCTION OF EQUIPMENT ALLOWS THE USER TO MAKE UP SYSTEMS WITH ANY NUMBER OF CONTROLLED FLIGHT AXES REQUIRED
DESIGN AND DEVELOPMENT UNDER CONTRACT NO. DA-36-039 SC-75040 WITH AVIONICS DIVISION, USASRDL, FT. MONMOUTH, N. J.
M-59-282

Fig 1

UNIVERSAL AUTOMATIC FLIGHT CONTROL SYSTEM

(FIXED WING, ROTARY WING AND DRONE AIRCRAFT)
TYPICAL INSTALLATION IN ARMY AIRCRAFT

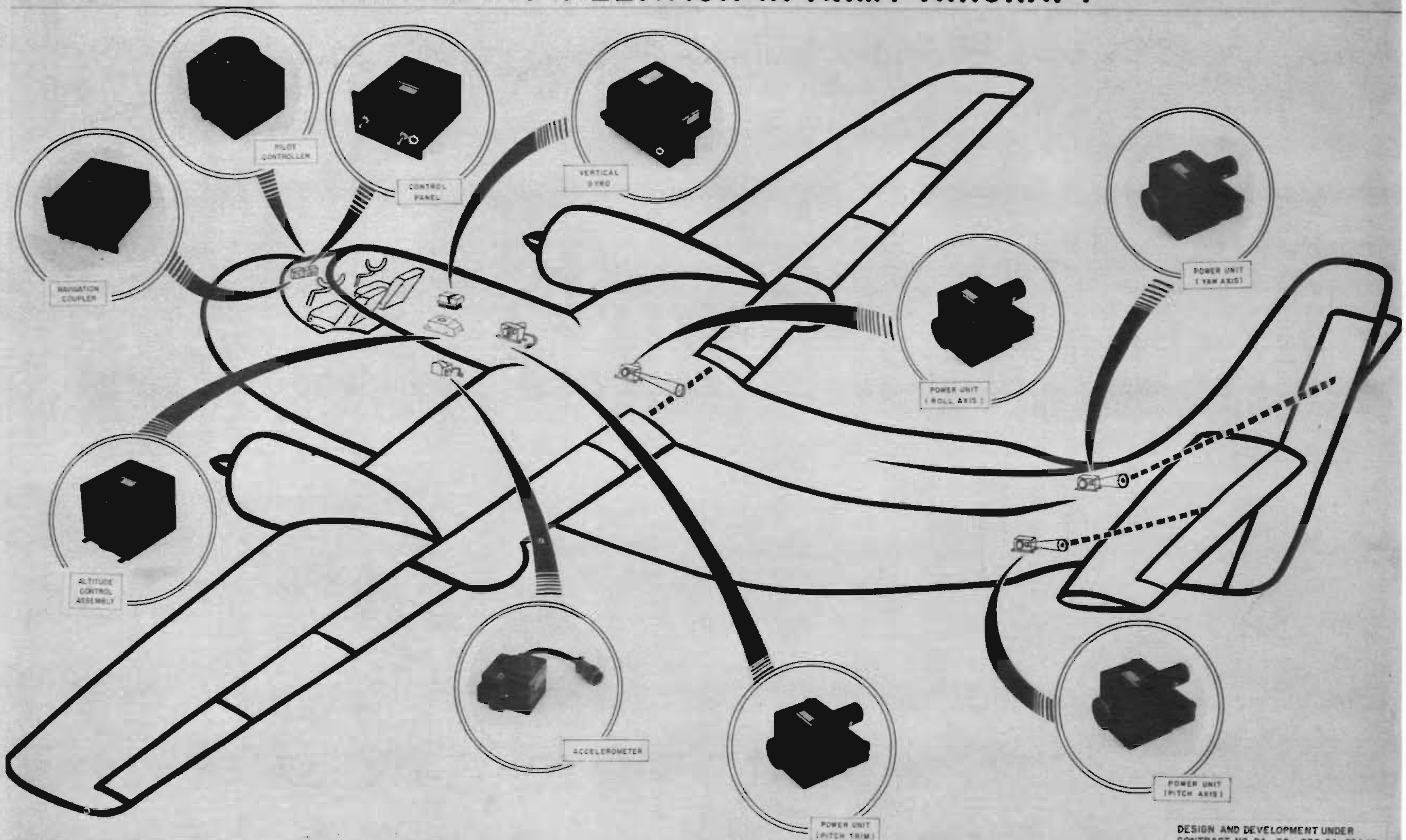

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Fig 2