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REMOTELY PILOTED VEHICLES
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A75-37669 RPV Simulation/Evaluation Program /RSEP/. J. P. Stovall (Westinghouse, Defense and Electronic Systems Center, Baltimore, Md.). In: NAECON '75; Proceedings of the National *Aerospace and Electronics Conferenc*, Dayton, Ohio, June 10-12, 1975. (A75-37623 18-01) New York, Institute of Electrical and Electronics Engineers, Inc., 1975, p. 384-392. 10 refs.

RSEP is two-part digital computer program which simulates the flight of RPV's engaged in a strike mission and evaluates the contribution of a candidate set of avionics to mission success. The principal avionics functions that are modeled in the simulation are navigation, communications, target acquisition and tracking and weapon launch. The evaluation portion of the program uses data from the simulation along with a realistic logic to account for the interrelationships among mission events in order to develop a set of overall measures of avionic system effectiveness. In the course of exercising RSEP for a number of candidate systems, it has been found to be a flexible tool for conducting tradeoffs and identifying preferred systems and techniques. (Author)

A75-37697 Imaging systems for RPV's. J. H. Meacham (Westinghouse Electric Corp., Systems Development Div., Baltimore, Md.). In: NAECON '75; Proceedings of the National Aerospace and Electronics Conference, Dayton, Ohio, June 10-12, 1975. (A75-37623 18-01) New York, Institute of Electrical and Electronics Engineers, Inc., 1975, p. 576-582.

Emerging RPV systems place new emphasis on the need for small, low power, imaging systems which fulfill the requirements of navigation and recovery, as well as target acquisition, identification, and designation. Design approaches are discussed which led to the development of a modular family of day/night imaging systems. Flight test data is used to support the selection of an appropriate system for a particular scenario. Areas covered include special signal processing techniques, sensor trade-offs, and solid state imaging systems. (Author)

A75-32452 # On the way to tactical aircraft robotics. W. B. Ballenberger (Sperry Rand Corp., Sperry Flight Systems Div., Phoenix, Ariz.). *Astronautics and Aeronautics*, vol. 13, June 1975, p. 28-35.

A radar control system for the F-102A aircraft is described. The PQM-102 target system, as it is designated, features a dual redundant (two sets of radar and controls) mobile ground station, a fixed ground station, and two fixed ground radar sources. The primary radar of the mobile ground station has a 50-n mi range and a 2-kW output; it controls the plane during takeoff and recovery and during close-in missions. The aircraft contains a 7.5-lb rod charge for destruct purposes and a scoring system consisting of four antenna assemblies containing two independent receiving elements, one horizontally and the other vertically polarized. Applications envisioned for the target system include interdiction, surveillance, reconnaissance, ECM, decoy, defense suppression, and air superiority. S.J.M.

A75-42323 RPV command and control. H. M. Federhen (ARPA, Washington, D.C.). *(Armed Forces Communications and Electronics Association, Annual Convention, 29th, Washington, D.C., June 3-5, 1975.) Signal*, vol. 29, Aug. 1975, p. 64-67.

The construction and testing of several prototypes has shown that the mini-RPV concept involving the use of lightweight remotely piloted vehicles for military reconnaissance, surveillance, and target acquisition applications is viable. Problems which have to be solved are related to the data links, including the control link from the ground station to the RPV, the telemetry link that reports RPV status, and the video downlink if one is used. A combination of techniques is to be used to provide satisfactory data links. The techniques make use of spread spectrum modulation, adaptive array antennas, and video bandwidth compression. G.R.

A75-25778 * # **A preliminary investigation of remotely piloted vehicles for airframe noise research.** D. J. Fratello and J. G. Shearin (NASA, Langley Research Center, Hampton, Va.). *American Institute of Aeronautics and Astronautics, Aero-Acoustics Conference, 2nd, Hampton, Va., Mar. 24-26, 1975, Paper 75-512.* 7 p. 6 refs.

Aircraft noise encountered in the community is caused predominantly by the aircraft engines. However, expected advances in engine noise technology combined with recent experimental evidence indicate that airframe (nonpropulsive) noise, may be a significant aircraft noise component in the future. Thus, methods for research into control of this type of noise are being evaluated and a technique based on the remotely piloted vehicle (RPV) concept appears to overcome some of the difficulties encountered with other test techniques. In particular, this paper presents sample experimental data, gathered during a preliminary RPV experiment, which illustrate the high signal-to-noise ratio attainable with this technique. Further, since the data are recorded as transients or nonstationary signals, a method of measurement and analysis is presented which increases statistical confidence in the results. (Author)

A75-37002 # **HASPA design and flight test objectives.** F. J. Petrone and P. R. Wessel (U.S. Naval Surface Weapons Center, Silver Spring, Md.). *American Institute of Aeronautics and Astronautics, Lighter Than Air Technology Conference, Snowmass, Colo., July 15-17, 1975, Paper 75-924.* 12 p. Navy-supported research.

In the early Fall of 1975 the first of four scheduled flights to be conducted in the High Altitude Superpressured Powered Aerostat (HASPA) Program will take place. The vehicle is a remotely piloted airship of some 800,000 cubic feet volume which will operate at an altitude near 70,000 feet. This paper briefly describes the evolution of the concept and presents a general design overview. The propulsion system and the different power supplies to be used on the three powered flights are described. The power supplies are primary Ag/Zn batteries, an H2/O2 fuel cell, and a solar array-secondary battery combination. These units are to provide both operating power and propulsion power for nominal periods of 30 hours, 7 days, and 30 days respectively. The flight test objectives and test measurement programs are described along with the launch, flight and recovery procedures. Most of the equipment being used in the test program has been designed to allow for maximum use of existing hardware which will minimize the program length and cost. (Author)

A75-41682 # **Optimal design of a Mini-RPV lateral autopilot.** I. Y. Bar-Itzhack (Technion - Israel Institute of Technology, Haifa, Israel) and E. Ferdman. *American Institute of Aeronautics and Astronautics, Guidance and Control Conference, Boston, Mass., Aug. 20-22, 1975, Paper 75-1121.* 10 p. 10 refs.

In this paper the design of a lateral autopilot for a miniature remotely piloted vehicle (RPV) is described. The structure of the autopilot is predetermined, as well as the measured variables. Even though aileron alone is used to control the RPV, the system is completely controllable. Using several indices of performance the best autopilot gains are determined by minimizing these indices. The minimization is carried out in the complex plane and comparison is made with state space methods. When a single error, such as heading error, is considered, the complex plane minimization procedure is superior. The RPV poles due to the Dutch roll mode stay close to the imaginary axis, although heavy penalty is imposed by the performance index on a persisting error. The pole placement is restricted by the fact that the trace of the system matrix is constant. Although no rudder is used, the vehicle executes coordinated turns due to its natural coordination quality. (Author)

A75-45014 Electronic warfare - Military needs propel mini-RPVs into tactical flight tests. R. T. Davis. *MicroWaves*, vol. 14, Sept. 1975, p. 34-36, 38-41.

Various new flight-tested mini-RPV prototypes are illustrated and explained. They range from 45 to 150 pounds in weight with engines of 2-14 horsepower, and most contain a TV camera and laser relay beam for homing in on targets by large bombing aircraft. Other possible payloads include radar jammers, simple decoys, and kamikazi warheads. The vehicles can be controlled directly from ground stations or through links with larger aircraft. S.J.M.

A75-45881 An analytical model for the control of low flying aircraft and vehicles by visual cues. A. Grunwald (Technion - Israel Institute of Technology, Haifa, Israel). *International Astronautical Federation, International Astronautical Congress, 26th, Lisbon, Portugal, Sept. 21-27, 1975, Paper ST-75-01*. 38 p. 6 refs.

This paper represents the development and experimental validation of an analytical model for manual visual field control (VFC) of aircraft. A basic model for the control oriented visual field information (VFI) is proposed and formulated in an optimal control framework. A special case of VFC is studied, namely, the manual lateral control of a TV-guided remotely piloted vehicle (RPV) along a straight reference trajectory in the presence of side gusts. For experimental validation, a five-degree-of-freedom fixed-base simulator has been constructed to simulate a RPV flight along a nominally straight reference trajectory. (Author)

A74-30598 # Experimental system for future remotely piloted vehicles. J. Spintzyk. *Dornier-Post* (English Edition), no. 2, 1974, p. 22-25.

Unmanned remote-controlled combat aircraft, known as remotely piloted vehicles or RPVs, may well acquire great importance, alongside the conventional manned aircraft. The German armed forces could save upkeep costs in peacetime with the aid of RPVs. Defence capability would not suffer thereby, since RPVs promise greater efficiency in operation. An especially interesting aspect is the use of RPVs against attacking armored units and other strongly defended ground targets in the combat area. The RPV system envisaged by Dornier consists of one or more vehicles, a flying relay station, and a mobile ground control station. F.R.L.

A75-11724 An inexpensive jet engine, dream or reality (Le réacteur bon marché, rêve ou réalité). Mr. Faury (Société d'Innovation et de Développement en Aérothermodynamique, Toulouse, France). *L'Aéronautique et l'Astronautique*, no. 47, 1974, p. 82-84. In French.

Discussion of the development of an expendable, short-lived jet engine of utmost design simplicity and suitable for mass production by processes of moderate tooling requirements, intended for the propulsion of remotely piloted vehicles for ground or sea attack, reconnaissance, illumination, decoy, interference, and target practice missions. A brief description of the French TRI 60 jet engine is presented. M.V.E.

A75-19580 # Target acquisition in remotely piloted vehicles. J. Spintzyk and P. Starke. *Dornier-Post* (English Edition), no. 3-4, 1974, p. 28-31.

Results of RPV missions flown against previously reconnoitred targets are discussed in re visual detection range, angular resolution, image aperture, target acquisition and engagement, and control station. Visual detection range fell off with darkness or poor target contrast; targets were recognizable with angular resolutions of 0.2 to 0.3 mrad/line; the smallest possible horizontal image aperture was the most efficient; a combination image sensor system working in two spectral ranges was the most promising solution to the target acquisition and engagement problem; and the control station design featured RPV controlled by one man (the pilot). S.J.M.

A75-15710 Chirping RPV data links for ECM protection. J. Otto (Harris Corp., Melbourne, Fla.). *MicroWaves*, vol. 13, Dec. 1974, p. 54, 56, 58, 60. USAF-ARPA-sponsored research.

A review is presented of the signal processing involved in a chirp modem for transmitting and receiving digital data for an RPV command link. SAW devices would have to be up and down converted to microwave frequencies if used for RPV communications. Signal processing with reflective-array compressors is considered along with the chirp modulator, jamming problems, and the prototype links developed. G.R.

A75-35261 The age of the RPV data bus or the data bus comes of age. L. C. Pico (Teledyne, Inc., Teledyne Ryan Aeronautical Div., San Diego, Calif.). In: Automatic support systems for advanced maintainability; Symposium, San Diego, Calif., October 30-November 1, 1974, Conference Record. (A75-35251 16-01) New York, Institute of Electrical and Electronics Engineers, Inc., 1974, p. 77-83.

The use of the airborne onboard processor to operate in a uniquely-controlled mode for self-validation, and subsequent validation of subsystems that are connected to a multiplexed digital data bus, are described. This multiplexed digital data bus concept permits avionics system evaluation without the need for several special test connectors interfacing at the interface unit, typical of the present computer test systems. This test concept eliminates the many measurement instruments traditionally used for this purpose. The processor instruction and priority schemes are used to individually address each RPV subsystem and conduct evaluations. Tests can be selectively structured to permit varying levels of test complexity. (Author)

A75-19712 • A manipulator system designed for Free-Flying Teleoperator Spacecraft. J. R. Tewell, R. A. Spencer, and J. J. Lazar (Martin Marietta Aerospace, Denver, Colo.). In: Human Factors Society, Annual Meeting, 18th, Huntsville, Ala., October 15-17, 1974. (A75-19676 07-54) Santa Monica, Calif., Human Factors Society, 1974, p. 493-497. 5 refs. Contract No. NAS8-30266.

A preliminary design of a manipulator system, applicable to a Free-Flying Teleoperator Spacecraft operating in conjunction with the Shuttle or Tug, is presented. The manipulator arm incorporates two 4-ft segments to the wrist with actuators located at the shoulder, elbow, and wrist. The wrist provides three degrees-of-freedom through pitch, yaw and continuous roll joints. An interchangeable end effector provides multiple task performance and satellite worksite versatility. A tip force of 10 lbs and a torque of 15 ft-lbs is provided. Man-in-the-loop simulations, using both unilateral and bilateral control techniques, were conducted. Based upon the simulation, a new, but relatively simple, control technique was proposed for the manipulator system. (Author)

A75-10623 Mini-RPV's for cheap and no risk air power. R. T. Davis. *MicroWaves*, vol. 13, Oct. 1974, p. 40-42, 44, 46-48. 5 refs.

Evaluated is low-cost technology to be used in mini-RPV aircraft with special attention given to reconnaissance and surveillance missions. Different video-compression techniques are described from the standpoint of frame-rate reduction, resolution reduction, and image transformation. The Advanced Research Projects Agency (ARPA) is evaluating three spread-spectrum techniques including direct sequence pseudo-noise, frequency hop, and chirp radar communications. A table summarizes the anti-jam margins that are possible by each spread-spectrum method. The building of a mini-RPV with C-band command and data links, called the Mark II and intended for army battle field support, is discussed. Present program efforts aim to develop propulsion units that will meet with military standards, secure up/down links, and a multiple RPV control system. T.S.

A74-45307 # Remotely piloted vehicles for the Army. V. Garber (U.S. Army, Office of Chief Scientist, Washington, D.C.). *Astronautics and Aeronautics*, vol. 12, Oct. 1974, p. 46-51.

Early developments concerning remotely piloted vehicles (RPV) during the time from 1956 to 1967 are briefly examined. After a short period of inactivity in this field the investigations concerning the development of RPVs were resumed following a study of the Defense Science Board in 1971. The group conducting the study recommended the development of an RPV for performing surveillance and target-acquisition missions within the range of conventional artillery. Another mission recommended involved the use of a miniature aircraft or slow-burning rocket in a 'Kamikaze' role to attack forward-element point targets of high value. Potential RPV applications were reviewed in the fall of 1973. Details and results of the various RPV-related studies conducted are presented, giving attention to the role of radar, automatic data processing, data links, symbolic displays, and radar cross section reduction. G.R.

A74-45308 # Air Force concepts for RPV application. J. A. Palmer (USAF, Aeronautical Systems Div., Wright-Patterson AFB, Ohio). *Astronautics and Aeronautics*, vol. 12, Oct. 1974, p. 52-56.

The RPVs are to complement the manned force and to increase its effectiveness. RPVs can, thus, provide escort jamming of enemy radars in support of a strike penetration. An RPV remotely controlled by a man can be used to conduct an important mission in a highly defended or politically sensitive area. Operational vehicles presently available possess a demonstrated ability to provide low- and high-altitude photo reconnaissance and signal intelligence in high-threat and/or poor-weather conditions. New uses of RPVs being considered include the relay of control signals and an employment as a wide-bank data link for transmitting images from TV or other sensors. High-altitude, long-endurance vehicles could provide continuous surveillance of ocean or land areas. Low-altitude mini-RPV could be used for real-time reconnaissance in a local battle area. G.R.

A74-45309 # RPV potential for naval applications. C. V. Bryan and J. H. Pennington (U.S. Naval Weapons Center, China Lake, Calif.). *Astronautics and Aeronautics*, vol. 12, Oct. 1974, p. 58-63.

Prime objectives for the employment of RPVs in naval warfare include tactical reconnaissance, open-ocean surveillance, anti-submarine warfare, strike support, airborne early warning, and command and control. However, some challenging problems remain to be solved before RPVs can play a vital role in sea control and projection of naval forces. A number of the technical and operational risk areas are considered, giving attention to data links, questions of target acquisition and identification, launch and recovery problems, the establishment of a shipboard control station, questions of maintainability and reliability, and aspects of airspace control. G.R.

A75-34725 # System concept and key problems concerning pilotless, remotely-controlled combat aircraft UKF (Systemkonzept und Schlüsselprobleme unbemannter, ferngelenkter Kampfflugzeuge UKF). J. Spintzyk and P. Starke (Dornier GmbH, Friedrichshafen, West Germany). *Deutsche Gesellschaft für Luft- und Raumfahrt, Jahrestagung, 7th, Kiel, West Germany, Sept. 17-19, 1974, Paper 74-076a*. 82 p. 19 refs. In German.

Pilotless, remotely-controlled flight vehicles show great promise for combat missions involving strongly defended ground targets. An employment of such unmanned aircraft is considered in the case of typical area targets in connection with the provision of air support and missions which have the objective to isolate the combat area. A description of the considered vehicle concept is given. Key problems are related to target recognition, data transmission, target search at the projection screen, flight control, and vehicle navigation. Attention is also given to an experimental system for the study of the various problem areas. G.R.

A75-26028 Remotely piloted LTA vehicle for surveillance. G. R. Seemann, G. L. Harris, G. J. Brown (Developmental Sciences, Inc., City of Industry, Calif.). In: Interagency Workshop on Lighter than Air Vehicles, Monterey, Calif., September 9-13, 1974, Proceedings. (A75-25969 10-05) Cambridge, Mass., MIT Flight Transportation Laboratory, 1975, p. 679-683.

The present work deals with the various aspects of a remotely piloted mini-LTA (lighter-than-air) vehicle for surveillance, monitoring and measurement in civilian and military applications. Applications, operations, and economics are discussed. A blimp design of about 5000 sq ft, 55 ft in length and 13 ft in diameter has been selected for the remotely piloted vehicle (RPV). Advantages of the LTA vehicle over current HTA craft include endurance, good top speed, low pollution, no minimum speed, low vibration levels, low maintenance, stable platform, safety to ground personnel and property, flexibility (versatility), economy, low operator skill requirements, low radar cross-section, and ease of launch and recovery.
S.J.M.

A74-40488 # Command and control challenge for RPVs. S. J. Colby, C. E. Franklin, and D. W. S. Prins (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). *Astronautics and Aeronautics*, vol. 12, Sept. 1974, p. 64-70.

Discussion of recent progressive developments and future trends in subsystem features of remotely piloted vehicles (RPVs). Subsystem advances for RPVs reflecting a broad base of technology in other military areas are reviwed, along with more general RPV developments. Special attention is given to such subsystems as 2-axis stabilized gimbal TVs, forward looking infrared radar with stabilized pointing mirrors, laser designators, RPV autopilots with sensors, 8000-word general-purpose computers, and onboard navigation aids. Areas of R&D inviting further efforts in the coming years are shown to include data processing, integration with command and control elements, and multisensor integration.
M.V.E.

A74-40487 # The Mini-RPV: Big potential - Small cost. K. Kresa and W. F. Kirlin (Defense Advanced Research Projects Agency, Washington, D.C.). *Astronautics and Aeronautics*, vol. 12, Sept. 1974, p. 48-62. 14 refs.

A large sample of representative accomplishments in the area of very small remotely piloted vehicles (Mini-RPVs) is reviewed, and the key considerations in their development and applications are discussed. Mini-RPVs are shown to offer endurance, stealth, punch, and large economies. Nowhere in the RPV family is the removal of man from the cockpit of such dramatic effect on size and weight reduction as in Mini-RPVs. In its basic form, a Mini-RPV includes in a gross weight of 20 to 140 lbs a sensor package weighing from 5 to 35 lbs, a data link sized to data rates and communications distances desired and generally weighing 1 to 5 lbs, some form of simple navigation and attitude control weighing less than 2 lbs, and an airframe, engine, and fuel making up the rest of the gross weight. The performance of these Mini-RPV systems spans penetration ranges from 10 to 150 nautical miles, with times on station from 1 to 3 hrs.
M.V.E.

A74-40486 * # RPVs - Exploring civilian applications. T. J. Gregory, R. O. Bailey, and W. P. Nelms (NASA, Ames Research Center, Moffett Field, Calif.). *Astronautics and Aeronautics*, vol. 12, Sept. 1974, p. 38-47. 15 refs.

Discussion of the civilian application possibilities for remotely piloted vehicle (RPV) systems. Following a listing of all possible desert, coastal, forest, agricultural, and urban RPV missions, a thorough examination is presented of such possible RPV aircraft applications as those of forest-fire detection and mapping. Some of the major obstacles to such civilian missions are also reviewed.
M.V.E.

A75-10186 **Drone/RPV systems.** W. W. Hemenway (USAF, Aeronautical Systems Div., Wright-Patterson AFB, Ohio). *Aeronautical Journal*, vol. 78, Aug. 1974, p. 355-362.

Consideration of the Remotely Piloted Vehicle (RPV) as a low cost system with applications in diverse roles of aerospace tactics. Special attention is given to the application of the RPV to aerospace power and system elements, and to the research and development activity currently underway. The drone/RPV design is discussed from the point of view of a total weapon system, with the control guidance as an essential element reviewed in detail. Additional programs and applications are Weather/Atmospheric Sampling, the Low Altitude Multi-Purpose Drone (LAMP), the Mini-Drone, and Drone Control and Data Retrieval System (DCDRS). T.S.

A74-43603 * **NASA Flight Research Center scale F-15 remotely piloted research vehicle program.** G. P. Layton (NASA, Flight Research Center, Research Projects Div., Edwards, Calif.). In: Advancements in flight test engineering; Proceedings of the Fifth Annual Symposium, Anaheim, Calif., August 7-9, 1974. (A74-43601 22-02) Lancaster, Calif., Society of Flight Test Engineers, 1974, p. 1-63 to 1-76. 5 refs.

The NASA Flight Research Center undertook a remotely piloted research vehicle (RPRV) program with a 3/8-scale model of an F-15 aircraft to determine the usefulness of the RPRV testing technique in high-risk flight testing such as spin testing. The results of the first flights of the program are presented. The program has shown that the RPRV technique, including the use of a digital control system, is a viable method for obtaining flight research data. Also presented are some negative aspects that have been learned about the RPRV technique in terms of model size, command frequency, and launch technique. (Author)

A74-41663 # V/STOL demonstrator vehicle for ejector thrust augmentation technology. J. M. Byrnes, R. D. Murphy, R. F. Ball, K. S. Nagaraja, D. L. Hammond, E. A. Langeben, and R. B. English (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio). *American Institute of Aeronautics and Astronautics, Aircraft Design, Flight Test and Operations Meeting, 6th, Los Angeles, Calif., Aug. 12-14, 1974, Paper 74-995.* 14 p. 14 refs

The objective of this effort was to design a vehicle for the inflight demonstration of an ejector thrust augmentation concept. The approach was a design arrangement and parametric study based on an off-the-shelf engine. The result is a small, remotely piloted vehicle (RPV) specifically designed as a V/STOL ejector concept. The size, or injection area ratio of the ejectors is an optimum 13.5, which produces a thrust augmentation ratio of 1.66, or a VTOL weight of 896 pounds. The ejector installation is fully vectorable from hover to a maximum speed of 227 knots, but its real payload potential is reflected by a 80 per cent overload capability with a 1000 foot STOL ground roll. At the VTOL weight, a 30+ gallon fuel payload gives a 100 minute endurance at sea level. (Author)

A74-39665 **Null-steering array for RPV application.** G. G. Rassweiler, G. P. Martin, L. M. Payne, and D. F. Lehman (Radiation, Inc., Melbourne, Fla.). In: International Conference on Communications, 10th, Minneapolis, Minn., June 17-19, 1974, Conference Record. (A74-39651 20-07) New York, Institute of Electrical and Electronics Engineers, Inc., 1974, p. 10E-1 to 10E-6. 6 refs. Contracts No. F30602-72-C-0396; No. F30602-73-C-0183.

Construction and testing of an analog adaptive null-steering array are described. This technique provides effective EMI protection and is particularly useful prior to signal acquisition when strong interferences and a weak signal are present. Null steering has been demonstrated to a depth of 30-45 dB with breadboard equipment that is not yet optimum. Biased interference suppression is the operative technique. Interference initially 20-40 dB greater than a desired signal source is found to be suppressed by 20-40 dB so that the interference to signal ratio equals one at the array output; the dominant interference simply suppresses itself in the array. Signal maximization (main beam pointing) is also achieved. A three-element adaptive array is presented, adaptive algorithms for the array control are given, and typical desired and jamming signal patterns are illustrated. Design improvements to minimize drift and intermods have been incorporated, and miniaturization by integrated circuit technology is underway. J.K.K.

A74-39684 **Functional command/control considerations for ship-deployable tactical remotely-piloted vehicle /RPV/.** R. E. Wehman (U.S. Naval Material Command, Naval Weapons Laboratory, Dahlgren, Va.). In: International Conference on Communications, 10th, Minneapolis, Minn., June 17-19, 1974, Conference Record. (A74-39651 20-07) New York, Institute of Electrical and Electronics Engineers, Inc., 1974, p. 108-1 to 108-4.

Examination of the technical requirements for effective and secure command/control/communications data links to and from a proposed ship-deployable remotely-piloted vehicle adaptable for use in tactical reconnaissance and/or targeting missions. Particular emphasis is given to two critical areas demanding higher performance capability than that afforded by current operational systems: (1) line-of-sight navigational tracking for extended ranges up to 100 miles over water under constantly-changing sea conditions; and (2) electronic countermeasures security of up and down links. (Author)

A74-26600 # Structural aspects of current RPV's. D. J. Mowrey (Teledyne Ryan Aeronautical Co., San Diego, Calif.). *AIAA, ASME, and SAE, Structures, Structural Dynamics and Materials Conference, 15th, Las Vegas, Nev., Apr. 17-19, 1974, AIAA Paper 74-346.* 12 p. 9 refs. Members, $1.50; nonmembers, $2.00.

A review of the current AQM-34, AQM-91, and BGM-34 series of remotely piloted vehicles (RPVs) discloses many structural design requirements similar to their manned counterparts. There are also numerous differences due to the RPV's unique requirements. The results of structural analyses and tests are shown in order to highlight the importance of the C-130 launch airplane upon RPV loads while captive. The important effects are from aerodynamic interference and from elastic structural response of the C-130. Simulation of the dynamics of parachute recovery illustrates the complex nature of this unique RPV structural requirement. Ground impact loads from tests are shown to be a function of recovery weight and the type of terrain upon which the impact occurs. (Author)

A74-27849 Stratospheric survey aircraft developed. *Aviation Week and Space Technology,* vol. 100, Apr. 15, 1974, p. 62, 63, 65.

A remotely piloted small-scale aircraft under development, intended to fly stratospheric survey missions with a ceiling of up to 100,000 ft, is examined. Termed the Mini-Sniffer, the canard aircraft will have a maximum gross takeoff weight of 145 lb and a payload of 25 lb. The two-stroke hydrazine monopropellant reciprocating engine (driving a variable-diameter propeller) is mounted in the aft pusher position to eliminate interference with the nose-mounted air sampling probes. The main wing is a high-aspect-ratio design with a span of 18 ft, an area of 35.5 sq ft, and a sweep angle of 20 degrees. V.P.

A74-26410 * # RPRVs - The first and future flights. R. D. Reed (NASA, Flight Research Center, Edwards, Calif.). *Astronautics and Aeronautics,* vol. 12, Apr. 1974, p. 26-42. 5 refs.

The merits of the RPRV (remotely piloted research vehicle) concept are discussed, along with its historical background and development culmination in the 3/8-scale F-15. The use of RPRVs is shown to be especially attractive when testing must be done at low cost, or in quick response to demand, or when hazardous testing must assure the safety of proceeding to manned vehicles. M.V.E.

A74-23392 American programs for reconnaissance vehicles and remotely piloted airplanes (Programmes américains d'engins de reconnaissance et d'avions pilotés à distance). *L'Aéronautique et l'Astronautique,* no. 43, 1973, p. 3-7. In French.

In their initial stage, pilotless planes flew along a programmed flight path or were guided by remote control. Most of them are now actually remotely piloted and are able in this way to perform a range of tasks wider than that of the sole reconnaissance missions. Following a brief review of the previous reconnaissance vehicle programs, the now current developments programs for pilotless airplanes designed for the reconnaissance, designation and attack of targets are detailed. (Author)

A74-14362 Remotely piloted vehicles - Necessity, wishful thinking, or plaything (Unbemannte Flugkörper - Notwendigkeit, Wunschdenken oder Spielerei). R. Olson. *Flug Revue/Flugwelt International*, Dec. 1973, p. 27-30, 35-38. In German.

Various types of remotely piloted vehicles (RPV) are considered, taking into account the military objectives for which the vehicles are to be used. RPV developed in Germany during the time from 1939 to 1945 are compared with RPV designed in the U.S. after 1945. Attention is given to the Matador TM-61C, the Mace TM-76, the Goose SM-73, the Regulus II, and the SNARK SM-62. Other RPV considered include the Jindivik MK.3, the Beechcraft PD-121, the Beechcraft KDB-1, the Radioplane RP-76, the Ryan Firebee, and the Radioplane XQ-4. Ground-to-air missiles are discussed together with the German space program in the years from 1935 to 1945 and unmanned VTOL platforms for military applications. G.R.

A73-45399 A review of the American RPV scene. I. Stambler. *Interavia*, vol. 28, Oct. 1973, p. 1070-1073.

The remotely piloted vehicle (RPV) can, in the opinion of its adherents, offer many of the capabilities of manned aircraft for a fraction of the cost. Applications being considered include several reconnaissance roles, electronic warfare systems, target acquisition, weapon delivery, air-to-air combat, and various combinations of these. Vehicles in hardware form include both expendable and nonexpendable systems. A number of current RPV projects undertaken by various manufacturers are reviewed. It is emphasized that electronics are vital to the success of the overall RPV concept. F.R.L.

A74-11576 Further development of the JT15D turbofan. R. H. Anschutz (United Aircraft Corp., Pratt and Whitney Aircraft Div., East Hartford, Conn.) and D. L. Cook (United Aircraft of Canada, Ltd., Longueuil, Quebec, Canada). *Society of Automotive Engineers, National Aerospace Engineering and Manufacturing Meeting, Los Angeles, Calif., Oct. 16-18, 1973, Paper 730919.* 13 p. Members, $1.25; nonmembers, $2.00.

When the JT15D engine was first considered for potential high-altitude, low flight speed, long-endurance RPV applications by the U.S. Air Force, the questions were: (1) will the engine run at these altitudes, (2) can it deliver the required thrust, (3) can it deliver the required power extraction, (4) what is the specific fuel consumption, (5) what oil system modifications are needed, (6) what is the optimum control system, and (7) are there other unknowns. A JT15D-4 turbofan engine, with only minor modifications which were easily incorporated into engines coming off the production line, proved more than adequate to achieve predicted endurance goals and measured performance. (Author)

A73-42533 # A technology tool for urban applications - The remotely piloted blimp. G. R. Seemann, G. L. Harris, G. J. Brown, and C. A. Cullian (Developmental Sciences, Inc., City of Industry, Calif.). *American Institute of Aeronautics and Astronautics and Public Technology, Inc., Urban Technology Conference and Technical Display, 3rd, Boston, Mass., Sept. 25-28, 1973, AIAA Paper 73-987.* 8 p. Members, $1.50; nonmembers, $2.00. Research sponsored by Developmental Sciences, Inc.

The remotely piloted blimp concept is to provide flexible, safe, economical airborne surveillance, measurement of monitoring systems for urban applications. The Traffic Eye, Enforcement Eye, and Enviro Eye are basically remotely piloted, ultra slow, low altitude buoyant airborne platforms equipped with television cameras. The flight characteristics of the blimp are discussed together with questions of control, takeoff, landing, and ground support. G.R.

A74-34846 # **Flight test evaluation of a low cost electrostatic autopilot.** C. D. Wandrey and D. K. Bergstrom (Lear Siegler, Inc., Astronics Div., Santa Monica, Calif.). In: Flight testing today - 1973; Proceedings of the Fourth National Symposium, Las Vegas, Nev., August 21-23, 1973. (A74-34837 16-02) California, Md., Society of Flight Test Engineers, 1973. 5 p.

The test and evaluation program described was conducted to gain insight into the concept of a simple RPV autopilot, and to obtain practical experience in its application. The test system is described and its theory is outlined. Particular attention is given to the solution of the major problems encountered in the program. Conclusions of recommendations derived from the test data are presented. V.P.

A74-25400 **Remotely piloted vehicles as remote sensing platforms.** J. A. Young (USAF, Aero Propulsion Laboratory and Materials Laboratory, Wright-Patterson AFB, Ohio). In: Remote sensing of earth resources; Proceedings of the Second Conference on Earth Resources Observation and Information Analysis System, Tullahoma, Tenn., March 26-28, 1973. Volume 2. (A74-25386 10-13) Tullahoma, Tenn., F. Shahrokhi, University of Tennessee, 1973, p. 269-280. 17 refs.

Technology advances have made possible a large number of useful and economical remotely piloted vehicles (RPV). The operation of several RPV's is described, and their possible use in remote sensing in the atmospheric and earth resources sciences is discussed. One advantage they may have over remote sensing satellites is that they can obtain greater data density and higher resolution. There are high, low, and intermediate altitude capability needs, various speed and range requirements, a number of structural demands, and a spectrum of payload requirements. Cost advantages are discussed in terms of the coupling of similar needs and vehicle requirements. P.T.H.

A73-15379 **Electronic warfare and remotely piloted vehicles.** C. S. Summers (USAF, Office of Scientific Research, Arlington, Va.). In: NTC '72; National Telecommunications Conference, Houston, Tex., December 4-6, 1972, Record. (A73-15376 04-07) New York, Institute of Electrical and Electronics Engineers, Inc., 1972, p. 2C-1 to 2C-3. 5 refs.

Discussion of electronic warfare tactics which may be employed against remotely piloted unmanned aircraft serving either for reconnaissance purposes or for weapons delivery. Deception and confusion of the vehicle control system by jamming and false-signal transmissions are examined along with possible capture of control over the vehicle. Countermeasures which may be designed into the vehicle include the use of highly directional antennas and sophisticated signal discrimination systems. T.M.

A73-37332 **Application of self-organizing control to remote piloting of vehicles.** R. L. Barron (Adaptronics, Inc., McLean, Va.) and R. A. Gagnon (USAF, Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio). In: Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. (A73-37301 19-11) Pasadena, Calif., California Institute of Technology, 1973, p. 409-422. 21 refs. USAF-supported research.

All electrooptical (E-O) and electromagnetic (E-M) instruments for remotely manned spacecraft and aircraft can measure phenomena indicative of the magnitude of the resultant bearing angle (boresight angle) between a fiducial axis in the instrument assembly and an external point target or signal source. It is shown that the remote piloting of vehicles can be materially aided by the use of simple E-O or E-M sensors in primary or backup control systems which can successfully employ self-organizing control logic to process input information under circumstances that would be highly confusing for the remote pilot, thus providing means to augment his actions or take over from him in automatic modes of control. F.R.L.

A72-28451 # RMVs in aerial warfare. W. D. Graham (RAND Corp., Santa Monica, Calif.). *Astronautics and Aeronautics*, vol. 10, May 1972, p. 36-47. 22 refs.

Factors forcing the interest in possible military uses of Remotely Manned Vehicles (RMVs) include the increasing lethality of antiaircraft defenses, the present level of vehicle and equipment costs, and the technological advances of the past ten years. The role of man during a combat mission is examined. It is found that man's presence is only needed when he, in effect, has to 'see' something - discriminate and decide. Now the technical means are available to displace these three functions too by communications and remote control. The great advantage of a RMV as a bomber is based on its ability to get close to the target before releasing free-fall ordnance. In general, the RMV weapon will find profitable application whenever air defenses can be expected to exact high loss rates. G.R.

A72-16556 Unified control systems. B. E. Keiser (Auditing Services of Virginia, Vienna, Va.). *IEEE Transactions on Aerospace and Electronic Systems*, vol. AES-7, Sept. 1971, p. 809-829. 13 refs.

A survey of the subject of unified control systems for the guidance of unmanned vehicles, such as pilotless aircraft and satellites, is presented. Unified refers to the fact that the tracking, telemetry, and command functions are all performed using a single rf channel and, at least ideally, a single set of equipment. The principles are outlined, followed by descriptions of several novel applications to the control of multiple vehicles. Examples based upon existing systems also are provided. (Author)

A71-35899 # Age of the RPV. William A. Anderson (Teledyne Ryan Aeronautical, San Diego, Calif.). *Teledyne Ryan Aeronautical Reporter*, vol. 32, Summer 1971, p. 2-9.

Evaluation of remotely piloted vehicles (RPV), the development of which has made possible a high degree of 'pilot' participation in areas where he functions best. The RPV concept is being considered for missions such as air superiority and weapons delivery, conducted in severely hostile environments. In these applications the goal is to maintain the advantages of manned flight through use of new sensors, data links, computers, and display systems without the disadvantages, such as life support systems, physical limitations, flight safety considerations, and loss of life. F.R.L.

A70-35822 # Negative G Drone aircraft surface tension fuel system. H. W. Barber and R. Lavi (Northrop Corp., Ventura Div., Newbury Park, Calif.). *American Institute of Aeronautics and Astronautics, Aircraft Design and Operations Meeting, 2nd, Los Angeles, Calif., July 20-22, 1970, Paper 70-910.* 5 p. Members, $1.25; nonmembers, $2.00.

The U.S. Navy MQM-74A Target Drone employs the surface tension principle in the fuel system to prevent air inclusion in the turbojet engine fuel during negative or zero g flight maneuvers. The system consists of two surface tension filters (screens) located in the fuel tank. The surface tension fuel pickup units are interconnected to the fuel pump intake and each is covered with a negative g hood. This system has the unique feature of eliminating moving parts normally found in aircraft fuel feed systems, i.e., flapper valves, check valves, accumulators, and dual-ended boost pumps. During negative g transients, the fuel trapped by the hood maintains positive contact with the surface tension screen. The liquid film bridging the screen pores forms a liquid membrane that resists gases from going through, while allowing a free flow of liquid across the screen pores. Continuous fuel flow is thus maintained throughout the vehicle flight maneuver and during adverse g transients. The MQM-74A surface tension fuel system has met design requirements and is operational. (Author)

A70-20625 LTV develops high-altitude recon drone.
Erwin J. Bulban. *Aviation Week and Space Technology*, vol. 92, Feb. 2, 1970, p. 56, 57, 59.

Discussion of a single-engine turboprop-powered aircraft for unmanned long-endurance electronic intelligence or tactical communications relay missions. The LTVE L450F is designed to handle missions lasting up to about 30 hr and operate at altitudes of more than 45,000 ft under remote control from stations up to 250 mi away. G.R.

A70-10515
VISUAL CONTROL USING WIDE ANGLE DISPLAYS (VISCON).
Floyd A. Kinder (U.S. Naval Weapons Center, China Lake, Calif.).
IN: PHOTO-OPTICAL TECHNIQUES IN SIMULATORS; SOCIETY OF PHOTO-OPTICAL INSTRUMENTATION ENGINEERS, SEMINAR-IN-DEPTH, SOUTH FALLSBURG, N.Y., APRIL 28, 29, 1969, PROCEEDINGS. (A70-10807 01-11)
Seminar co-sponsored by the Simulation Councils.
Redondo Beach, Calif., Society of Photo-optical Instrumentation Engineers (SPIE Seminar Proceedings. Volume 17), 1969, p. 103-105.

Description of a TV system for controlling a QF-9 drone aircraft in landings and takeoffs and for in-flight control of the BQM-34A target drone in test operations. This system consists of an onboard camera transmitting to a standard TV monitor on the ground as an adjunct to the regular target drone remote controls. The QF-9 remote-control flights were pattern flights with touch-and-go landings using a TV camera with a 30-deg field-of-view lens. Several BQM-34A flights were made with 60-, 30-, and 20-deg field-of-view lenses, which resulted in good visual references and sighting of 60-ft boats at ranges of 5 to 10 miles. The 10-mile sighting was made using a camera with a 30-deg field of view. M.M.

A69-34505
OPERATIONAL SYSTEM EFFECTIVENESS STUDY - A LAYMAN'S APPROACH.
Hans Reiche (Department of National Defence, Canadian Forces Headquarters, Ottawa, Canada).
IN: ANNUAL SYMPOSIUM ON RELIABILITY, CHICAGO, ILL., JANUARY 21-23, 1969, PROCEEDINGS. [A69-34476 18-15]
Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control.
New York, Institute of Electrical and Electronics Engineers, Inc. (Annals of Assurance Sciences. Volume 2, No. 1), 1969, p. 263-269.

Description of a development program to design methods of providing operational system-effectiveness information for a reconnaissance drone system. A simple model was developed and special recording forms were prepared for gathering information during the various phases, including test flights. A feedback system was developed to show the need for, and to assist in the design of any changes that might be required. The information was also used to plot the growth potential of reliability and maintainability parameters. The results of the study led to decisions on tradeoffs in the final configuration. Although the project was modest in dimension, with only one engineer and two technical assistants, it was adequate to provide project management with sufficient data to make management decisions. B.H.

A66-23348 #
DESIGNING THE ON-BOARD STABILIZATION CIRCUIT FOR A PILOTLESS AIRCRAFT [O FORMIROVANII BORTOVOGO KONTURA STABILIZATSII BESPILOTNOGO LETATEL'NOGO APPARATA].
I. V. Ostoslavskii and I. V. Strazheva.
IN: INVESTIGATIONS OF FLIGHT DYNAMICS [ISSLEDOVANIIA PO DINAMIKE POLETA].
Edited by I. V. Ostoslavskii.
Moscow, Izdatel'stvo Mashinostroenie, 1965, p. 308-337. 5 refs.
In Russian.

Discussion of the problem of designing the on-board stabilization circuit of a drone aircraft to provide satisfactory transmission of the control signals over the required frequency range, and a satisfactory transient response irrespective of the noise background. For known characteristics of the autopilot, the problem is shown to reduce to the determination of the transfer-function coefficients - i.e., to the determination of a rational position of the aircraft's center of mass. The initial equations and transfer functions are examined for a longitudinal and a lateral motion of the aircraft. V.P.

A64-17379
COMMAND GUIDANCE SYSTEM FOR DASH.
Robert O. Blackert (Motorola, Inc., Franklin Park, Ill.).
Engineering Bulletin, vol. 12, no. 1, 1964, p. 14-19.

Description of the command guidance system for the Drone Anti-Submarine Helicopter (DASH). A digital system was developed, utilizing a simplified message format which permits accurate control of several drones in the target area. The coder unit, which generates the necessary timing signals and translates information received from the control unit, is described. The command information is picked up by an FM receiver aboard the drone, and the decoder translates the command information into orders for the drone flight controls and armament mechanisms. High reliability is achieved. The DASH system is operational on several ships.

A64-26791
AN ACOUSTIC ARMING/SAFING SYSTEM FOR WEAPONS CARRIED BY DRONE HELICOPTERS OF THE U.S. NAVY.
James A. Rummell (General Precision, Inc., Librascope Div., Glendale, Calif.).
IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.
Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers.
Edited by B. J. Goldfarb.
North Hollywood, Western Periodicals Co., 1964, p. 474-478.

Report of studies and tests which reportedly have shown the feasibility of using acoustic energy as an arming/safing communications link between a drone helicopter and its weapon and between a ship and a drone helicopter. The acoustic link is considered to have several advantages over conventional methods of arming and safing: (1) it eliminates the problem of electromagnetic compatibility and thus will not cause accidental detonation of explosive materials; (2) it will not require an RF allocation and therefore will not increase the crowding of the radio spectrum; (3) it is highly resistant to enemy countermeasures; and (4) having a relatively short range, it will not compromise the security of the ship, the drone helicopter, or the weapon. It is suggested that the completed studies should be followed by a breadboard hardware development program to verify the choice of frequencies and demonstrate system operation in a shipboard environment. D. H.

A64-14074
THE ROTARY WING DRONE - A MISSION MULTIPLIER.
Daniel T. Bernard (Kaman Aircraft Corp., Electronic Systems Div., Bloomfield, Conn.).
Verti-Flite, vol. 10, Jan. 1964, p. 2-8.

Discussion of the mission capabilities of the rotary wing drone helicopter. Briefly described are the stages that led to the drone's capability of being operated both on the ground or from another aircraft, and finally of being flown pilotless. Described in detail is the Universal Drone System called "Unidrone" because of its versatility with regard to all types of aircraft, and its capability to utilize the "building block" concept, adapting itself to simple or sophisticated missions commensurate with prescribed costs. It is noted that this type of system is ideal for general purposes and certainly for tactical type missions, but, for limited type of missions and for use as target drones, it may prove somewhat costly because of its relative complexity due to continuous proportional data transmission required for the Earth-oriented reference system. Shown is a block diagram of the airborne equipment, as well as of the simple Unidrone ground control station with all the functions on the remote controller. Listed are some of the more obvious mission extensions well adapted to the robot helicopter.

A63-23266
DESIGN PHILOSOPHY OF AN AUTOMATIC CHECKOUT AND LAUNCH SYSTEM FOR A DRONE.
Harry Halton (Canadair, Ltd., Montreal, Quebec, Canada).
(Institute of Electrical and Electronics Engineers, International Conference and Exhibit on Aerospace Support, Washington, D. C., Aug. 4-9, 1963.)
IEEE Transactions on Aerospace, vol. AS-1, Aug. 1963, p. 538-546.

Description of a system by means of which a drone can be automatically checked out and launched from a remote location over a period of less than 12 min from "go-ahead" by relatively low-skilled personnel. The features of the system are its simplicity, the rapidity with which the complete sequence is accomplished, and the ease of fault recognition. Discussed is one of the design problems solved: the automatic control and monitoring of turbojet engine operation.

A63-18603
THE DASH WEAPON SYSTEM.
A. J. Pappas and E. W. Strong (Gyrodyne Company of America, Inc., St. James, N. Y.).
American Helicopter Society, Newsletter, vol. 9, Apr. 1963, p. 2-8.

Description of the various factors that have led to the development of the DASH (Drone Anti-Submarine Helicopter) as part of the destroyer weapons system. Drone experiments using the QH-50A, the QH-50B, and the QH-50C turbine-powered helicopters having accommodations for a safety pilot, are covered in chronological order. Design and performance characteristics of the helicopter, which are also applicable to a number of other military missions, are presented.

A63-14972
FLIGHT TESTING OF DRONE HELICOPTERS.
Alexander J. Pappas (Gyrodyne Company of America, Inc., St. James, N. Y.)
New York Academy of Sciences, Vertical Take-Off and Landing (VTOL) Aircraft Conference, New York, N. Y., Dec. 10-12, 1962.)
New York Academy of Sciences, Annals, vol. 107, art. 1, Mar. 25, 1963, p. 25-39.

Presentation of an approach to the flight testing of helicopter drones. Specifically considered is the Gyrodyne DSN-3 pure-drone helicopter, based on the DASH (Drone Anti-Submarine Helicopter) concept developed by the U.S. Navy. Studies of landing problems led to the development of the automatic landing system known as LAD (Landing Assist Device), which is described briefly. A summary is given of the progress made since initiation of the DSN-1 program to the present.

A63-12825
VERSUCHE DER CONTRAVES MIT FERNGELENKTEN FLUGKÖRPERN [CONTRAVES' TESTS WITH GUIDED DRONES].
Flugwehr und -Technik, vol. 25, Jan. 1963, p. 9-11. In German.

Description of tests carried out in Switzerland with the U.S.-supplied Beech Target Drones, with particular attention to guidance and the flight program. In addition, some structural and design characteristics of the drones are presented.

62-10684 HELICOPTER DRONES. Cannonade, vol. 14, Sept.-Oct. 1962, p. 2, 3.

Description of the principles and operation of an electronic system which enables helicopters to be flown by ground operators. With this drone system, ground operators can put helicopters through all the maneuvers performed by manned rotorcraft in crosswinds up to 30 mph, at altitudes up to 8,000 ft, and at distances up to 15 miles. The capabilities of helicopter drones are also discussed.

61-8676 MICROWAVE COMMAND GUIDANCE - VERSATILE SYSTEM FOR DRONE CONTROL. W. B. Sheffield and L. H. Hagler. Missiles & Space, vol. 7, July 1961, p. 30-33. Description of a drone control system that integrates tracking, guidance, and telemetering functions by an interrogator-beacon system with identity, command, and flight data superimposed on the radar beam by pulse code modulation. The system demonstrated a high degree of reliability and is adaptable to the control of extraterrestrial traffic.

61-8095 LES ENGINS D'OBSERVATION. Jean-Marie Vauchy. L'Air et l'Espace, May 1961, p. 41-43. In French. Brief discussion of surveillance drones, covering their tactical necessity, required characteristics, navigation systems, and observation systems. Reference is made to the Radioplane (Northrop) SD-1, Aerojet-General SD-2, Republic SD-4, and Fairchild SD-5.

61-6172 TARGET AND RECONNAISSANCE DRONES. Interavia, vol. 16, May 1961, p. 667-675. Survey of current developments in the field of drones. The variety of missions which drones are able to perform, and the configurations and types of engines employed in specific applications, are reviewed. Particular attention is given to the use of drones for target practice and reconnaissance. Methods of transport, launching, guidance and control, and recovery are discussed in some detail. A table, listing the characteristics of drones produced by Australia, France, Holland, Italy, Japan, and the U.S., is presented.

61-4079 SUPERSONIC TARGET DRONES. T. L. Trexler. Ordnance, vol. 45, May-June 1961, p. 882-885. Discussion of ramjet target drones developed by Lockheed Missile and Space Division and of factors which contribute to their advantages as targets for anti-missile weapons.

61-8248 THE HYDRAULIC MUSCLE: A SOLUTION TO THE MISSILE AND DRONE CONTROL SURFACE ACTUATOR PROBLEM. H. W. Avery and T. S. [illegible]nda. Missiles & Space, vol. 7, Apr. 1961, p. 22-24, 44, 45. Description of a simple, low-cost actuator made of two sections of standardized hose connected mechanically by a four-way hydraulic servovalve acting in a push-pull fashion and realizing a work output of 1 in. per 20 in. of hose assembly, by means of an axially acting fluid pressure force. Parameters of entrained volume and effective area in force delivery have been established experimentally, and analytic correlations between hydraulic muscle and piston-type actuator have been made, some of which are presented.

61-5071 UNITED STATES AIRCRAFT - MILITARY DRONES; MAPPING, SURVEILLANCE, TARGET. Western Aviation, Missiles & Space (33rd Annual Directory), vol. 41, Apr. 1961, p. 105-107. Presentation of performance characteristics for 24 types of military drones.

61-7064 ADLERÄUGIGE ZWERGE. Stefan Geisenheyner. Flug-Revue, Mar. 1961, p. 15, 16. In German. Discussion of developments in reconnaissance aircraft. The background history of the short-range unmanned reconnaissance aircraft is given, and the instrumentation and operation of drones are considered.

61-1579 TARGETS AND DRONES. Flight, vol. 78, Dec. 23, 1960, p. 986-992. Review of American, Australian, British, and French-developed targets and drones. Applications, design data, and equipment are discussed.

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Scientific and Technical Aerospace Abstracts

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N75-31047*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.

THE INFLUENCE OF RADIO ALTIMETER ERRORS ON PILOT PERFORMANCE DURING THE FINAL APPROACH AND LANDING PHASE OF AN RPV MISSION

James C. Howard Jul. 1975 18 p refs

(NASA-TM-X-62466; A-6219) Avail: NTIS HC $3.25 CSCL 17G

Due to the fact that remotely piloted vehicles (RPV's) are currently being flown from fixed base control centers, kinesthetic and real world peripheral vision cues are absent. The absence of these cues complicates the piloting task, particularly during the final approach and landing phase of a mission. The pilot's task is futher complicated by errors in the displayed altitude information. To determine the influence of these errors on pilot performance during the final approach and landing phase of a mission, an experiment was conducted in which pilot subjects were asked to fly a fixed base simulation of a Piper PA-30 aircraft, using degraded altitude information. For this experiment, the chevron component of the display configuration was driven by a radio altimeter. Four altimeters were used, each with a different error characteristic, but within the range specified for the Sperry series of radio altimeters. Results indicate that for range of errors considered, there is no significant difference in landing performance that can be attributed to errors in altitude information. Author

N75-31118# Naval Air Development Center, Warminster, Pa. Vehicle Technology Dept.

USER'S GUIDE FOR SIX-DEGREE-OF-FREEDOM DIGITAL COMPUTER AIR VEHICLE SIMULATION

James C. Duke 16 Apr. 1975 157 p refs

(AD-A009474; NADC-74258-30) Avail: NTIS CSCL 01/3

This report is a user's manual for a NAVAIRDEVCEN (Naval Air Development Center) developed 6DOF (six-degree-of-freedom), air vehicle stability, performance, and control digital computer simulation. Included are descriptions of the coordinate systems, the aerodynamic, thrusting, and inertial forces and moments acting upon the vehicle, the equations of motion, and the atmosphere model. Discussions of such user oriented information as the selection and specification of run parameters, data implementation procedures, as well as a sample program listing with related flow charts are included. GRA

N75-30150# Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio.

AMRL REMOTELY PILOTED VEHICLE (RPV) SYSTEM SIMULATION STUDY 2: RESULTS

Robert G. Mills, Robert F. Bachert, and Milss M. Aume Feb. 1975 40 p

(AF Proj. 7184)

(AD-A006142; AMRL-TR-75-13) Avail. NTIS CSCL 01/3

The AMRL RPV System Simulation and Research Program was initiated in April 1973 in response to requirements for support of the design of the man-machine/environment interface of AF RPV systems. The major objectives of the AMRL RPV System Simulation and Research Program are as follows: (1) perform RPV system design evaluation studies, i.e., evaluate alternative design configurations, assumptions, operating procedures, etc.; (2) assess RPV system effectiveness, i.e., evaluate the expected effectiveness of a given system configuration such as its overall probability of achieving a target, etc.; (3) provide man-machine/environment interface engineering data, i.e., evaluate effectiveness of contractor designed consoles, video bandwidth compression techniques. GRA

N75-15862# Naval Undersea Warfare Center, San Diego, Calif.
IMAGE TRANSMISSION VIA SPREAD SPECTRUM TECHNIQUES Quarterly Technical Report, 2 Jan. - 1 Jul. 1974
Robert W. Means, Jeffrey M. Speiser, and Harper J. Whitehouse 1974 130 p refs
(ARPA Order 2303)
(AD-787502; QTR-4) Avail: NTIS CSCL 17/2

This report addresses the design of a spread spectrum image transmission system to provide increased antijam protection to a television link from a small remotely piloted vehicle. Previous quarterly reports have described component developments, theoretical advances in image processing, and simulations of proposed coding schemes. This report summarizes the proposed total system. Author (GRA)

N75-10912* National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
NASA FLIGHT RESEARCH CENTER SCALE F-15 REMOTELY PILOTED RESEARCH VEHICLE PROGRAM
Garrison P. Layton *In* Soc. of Flight Test Engr. Advan. in Flight Test Eng. 1974 14 p refs (For availability see N75-10910 02-05)
CSCL 01B

A remotely piloted research vehicle (RPRV) program was conducted with a 3/8-scale model of an F-15 airplane to determine the usefulness of the RPRV testing technique in high risk flight testing such as spin testing. The results of the first flights of the program are presented. The program has shown that the RPRV technique, including the use of a digital control system, is a viable method for obtaining flight research data. Also presented are some negative aspects that have been learned about the RPRV technique in terms of model size, command frequency, and launch technique. Author

N75-28059# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
A DESIGN STUDY FOR A REMOTELY PILOTED VEHICLE, AUTOMATIC LANDING SYSTEM M.S. Thesis
Mark P. Hadley Dec. 1974 111 p refs
(AD-A005285; GE/MA/74D-4) Avail: NTIS CSCL 01/3

A method of control design is developed using optimal control theory which results in a simple and practical control system. The basis of this method is the elimination of unnecessary feedback gains which in turn allows most of the Kalman filter elements to be eliminated also. The procedure is developed by designing an automatic control system for a remotely piloted vehicle. The aircraft modeled in the study was the Ryan Compass Cope RPV. This aircraft has a low wing loading making it very susceptible to wind gusts. The problem is limited to the approach phase of landing under moderate to severe turbulence. Both longitudinal and lateral control systems are considered. GRA

N75-25920# Rock Island Arsenal Lab., Ill. General Thomas J. Rodman Lab.
ESTIMATION OF LOCATING ERRORS AND RESOLUTION OF AN RPV/CLGP SYSTEM
Leonard B. Gardner and Dick A. Bergren Dec. 1974 48 p refs
(Contract DAAA09-74-C-2051)
(AD-A003957; RIA-R-TR-74-040) Avail: NTIS CSCL 01/3

Mini-RPV is considered as part of the CLGP Weapon system for the purpose of locating and designating targets for tube artillery systems. The errors of several different types of instrumentation payloads and airframes are estimated and compared to the locating errors for forward observers. GRA

N75-21277# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.

COST ESTIMATING RELATIONSHIPS FOR PROCUREMENT COSTS OF AIRBORNE DIGITAL COMPUTERS AND INERTIAL MEASUREMENT UNITS FOR USE IN REMOTELY PILOTED VEHICLES M.S. Thesis

Kenneth V. Funkhouser Dec. 1974 82 p refs

(AD-A003353; GSA/SM/74D-3) Avail: NTIS CSCL 01/3

Parametric cost estimating relationships (CER's) are developed to predict procurement costs of airborne digital computers and inertial measurement units which are suitable for use in remotely piloted vehicles (RPV's). The CER's predict first unit recurring cost in 1974 dollars and can be incorporated with an appropriate learning curve to estimate average cost for a given production quantity. A brief discussion of a computerized parametric cost estimation technique, the RCA PRICE model, is provided to compare methodology, input requirements, and output. The predictive capabilities of the RPV CER's are compared to avionics procurement CER's developed by the Air Force Avionics Laboratory. The RPV CER's are generally more accurate than the AFAL CER's when procurement costs of equipment usable in remotely piloted vehicles are being estimated. GRA

N75-20253# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.

COMPUTER SIMULATION OF MAINTENANCE FOR MULTI-MISSION RPV'S M.S. Thesis

Paul R. Sheridan Dec. 1974 104 p refs

(AD-A003351; GSA/SM/74D-8) Avail: NTIS CSCL 01/3

The purpose of this research project was to develop a computer simulation model of maintenance for a multi-mission RPV. The model is developed with as much flexibility as possible consistent with the expressed desires of the RPV SPO at Wright-Patterson AFB, Ohio. A method of analyzing the output of the simulation to determine trade-offs between the use of manpower and vehicles is also developed and a numerical example is presented. The greatest value of this research is the potential for use in various areas of study concerning RPV maintenance. This report does not address questions of operational effectiveness of MMRPVs in the target area. GRA

N75-10936*# National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.

A REMOTELY AUGMENTED VEHICLE APPROACH TO FLIGHT TESTING RPV CONTROL SYSTEMS

Dwain A. Deets and John W. Edwards Nov. 1974 26 p

(NASA-TM-X-56029; H-870) Avail: NTIS HC $3.75 CSCL 01C

A remotely augmented vehicle concept for flight testing advanced control systems was developed as an outgrowth of a remotely piloted research vehicle (RPV) program in which control laws are implemented through telemetry uplink and downlink data channels using a general purpose ground based digital computer which provides the control law computations. Some advantages of this approach are that the cost of one control system facility is spread over a number of RPV programs, and control laws can be changed quickly as required, without changing the flight hardware. The remotely augmented vehicle concept is described, and flight test results from a subscale F-15 program are discussed. Suggestions of how the concept could lead to more effective testing of RPV control system concepts, and how it is applicable to a military RPV reconnaissance mission are given. Author

N75-29099# Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.
FULL-SCALE AERODYNAMIC AND ENGINE TESTING OF THE APL SYMDEL Mk 6 RPV
R. H. Cramer and M. L. Hill Oct. 1974 133 p refs
(Contract N00017-72-C-4401)
(AD-A006283; APL-TR-1257) Avail: NTIS CSCL 01/3

This report presents documentation of the wind tunnel testing of the APL Symdel Mk VI remotely piloted vehicle (RPV). The purpose of these tests was to determine the aerodynamic features, live engine performance, and active control servo responses of the RPV. Standard six component aerodynamic data are given for six alternative configurations. GRA

N75-10079# Army Electronics Command, Fort Monmouth, N.J.
A STUDY OF STABILIZATION TECHNIQUES FOR SMALL, FIXED-WING, REMOTELY PILOTED AIRCRAFT Final Report
A. W. Campagna and R. E. Pribyl Aug. 1974 124 p
(DA Proj. 67372512-K-2101)
(AD-784109; ECOM-4239) Avail: NTIS CSCL 01/3

This report is concerned with the dynamic response of small, fixed wing RPV's to atmospheric disturbances. Several alternative control techniques were modeled and implemented in a hybrid simulation, and an assessment of relative performance was made. Author (GRA)

N75-15658# Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.
ENGINE DEVELOPMENT PROGRAM FOR THE APL REMOTELY PILOTED VEHICLE
T. R. Small Jul. 1974 35 p
(Contract N00017-72-C-4401)
(AD-787507; APL-TG-1249) Avail: NTIS CSCL 01/3

Performance of a custom-built (Sakert-Riggs) two-cylinder glow plug engine for use in the APL Remotely Piloted Vehicle was tested. Output power was less than expected, and plans to modify the engine to increase its power were foiled because of the early discovery of a structural weakness that showed up in every unit tested. An alternate engine was then developed, based on a low-cost proven design (McCulloch) that had been in quantity production for a number of years. This engine showed higher peak power and weighs more, but requires less than one-fourth the fuel at cruise power, primarily because it uses spark plug ignition with gasoline rather than glow plug ignition with methanol. Late in the test program, another brand (Kolbo) custom-built two-cylinder glow plug engine was introduced. Limited testing showed it to be a satisfactory, lightweight, but fuel-hungry engine. Author (GRA)

N74-28507*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
PRELIMINARY PERFORMANCE ESTIMATES OF AN OBLIQUE, ALL-WING, REMOTELY PILOTED VEHICLE FOR AIR-TO-AIR COMBAT
Walter P. Nelms, Jr. and Rodney O. Bailey Washington Jul. 1974 105 p refs
(NASA-TN-D-7731; A-5338) Avail: NTIS HC $4.50 CSCL 01C

A computerized aircraft synthesis program has been used to assess the effects of various vehicle and mission parameters on the performance of an oblique, all-wing, remotely piloted vehicle (RPV) for the highly maneuverable, air-to-air combat role. The study mission consists of an outbound cruise, an acceleration phase, a series of subsonic and supersonic turns, and a return cruise. The results are presented in terms of both the required vehicle weight to accomplish this mission and the combat effectiveness as measured by turning and acceleration capability. This report describes the synthesis program, the mission the vehicle, and results from sensitivity studies. An optimization process has been used to establish the nominal RPV configuration of the oblique, all-wing concept for the specified mission. In comparison to a previously studied conventional wing-body canard design for the same mission, this oblique, all-wing nominal vehicle is lighter in weight and has higher performance. Author

N74-34188# Texas Instruments, Inc., Dallas Electro-Optics Div.
MULTIPURPOSE INFRARED SYSTEMS (MIRS III) Final Report
28 Jun. 1974 277 p
(Contract F33615-73-C-1328)
(AD-782200; AFAL-TR-74-215) Avail: NTIS CSCL 17/5

The objective of this program was to advance the state-of-the-art technology for low cost; low weight; thermal imaging systems for remote piloted vehicles. The principle areas of study a ; in automatic focus compensation, structures, optic system designs and electronic multiplexing methods. The report covers preliminary designs for three types of FLIR systems and predicts quantity cost of production for quantities of 100 and 500. This report also includes design data that allows the application of technology to the reduction of piece p rt costs by using plastic parts. In this manner, temperature compensation of refractive optical systems, and compensated reflective optical systems, can be fabricated with improved performance and reduced weight. Valuable fall-out of this study includes: techniques that can be used in manned aircraft systems to improve performance, make them simpler to operate, and reduce system power and weight requirements. GRA

N74-33474# Decision Science, Inc., San Diego, Calif.
PRINCIPLES OF DISPLAY AND CONTROL DESIGN FOR STRIKE REMOTELY PILOTED VEHICLES RPVs Final Report
Lawrence J. Fogel, Carl E. Englund, Michael L. Mout, and Thomas D. Hertz Jun. 1974 158 p refs
(Contract N00014-72-C-0196)
(AD-782581) Avail: NTIS CSCL 01/3

Principles of display and control design for Remotely Piloted Vehicles (RPVs) were investigated. The difficulties which arise from lack of kinesthetic feedback and problems associated with communicating adequate information to the remote pilot were considered. Attention was focused on the strike mission. A series of experiments were conducted to examine the pilot/subject's ability to control the RPV in flight and perform certain targeting maneuvers under different display and control situations. (Modified author abstract) GRA

N74-31465 Vereinigte Flugtechnische Werke-Fokker G.m.b.H., Bremen (West Germany).
PRELIMINARY DESIGN TECHNIQUES FOR UNMANNED, REMOTE PILOTED VEHICLES
R. Staufenbiel and H. Schmidtlein *In* AGARD Aircraft Design Integration and Optimization, Vol. 1 Jun. 1974 14 p (For availability see N74-31458 21-02)

The steps involved in the design of remotely piloted vehicles are discussed. Specific areas of concern are: (1) combat tactics, (2) weaponry, (3) sensors, (4) payload and range, (5) guidance and control, and (6) maintainability, storability, and vulnerability. The characteristics of a typical RPV are analyzed to provide an example of the important factors which are involved in the design procedure. Author

N74-22636*# Kanner (Leo) Associates, Redwood City, Calif.
REMOTELY PILOTED VEHICLES: NECESSITY, WISHFUL THINKING OR PLAYTHING
R. Cisen Washington NASA May 1974 34 p Transl. into ENGLISH from the German report "Flug Revue/Flugwelt International" Dec. 1973 p 27-30, 35-38
(Contract NASw-2481)
(NASA-TT-F-15580) Avail: NTIS HC $4.75 CSCL 01C

A survey is made of the various classes of unmanned flying craft and their applications, and their history is outlined, covering balloons, drones, early missiles, guided missiles, the German space program prior to and during WW II, and VTOL equipment. The most important military uses for RPVs are concluded to be reconnaissance and transport, the latter also possessing spinoff value for the civilian sector. Fighter RPVs are found to be ineffectual, whereas the one-way delivery of weapons has proven quite feasible. Author

N72-22034# RAND Corp., Santa Monica, Calif.
AIRFRAME STRUCTURAL MATERIALS FOR DRONE APPLICATIONS
Donald F. Adams Jul. 1971 49 p refs
(Contract DAHC15-67-C-0141; ARPA Order 189)
(AD-736616; R-581/4-ARPA) Avail: NTIS CSCL 01/3

A comparison was made of performance, weight, and cost characteristics of a wide range of structural materials for aircraft. Materials ranging from polyester-impregnated paper and wood to titanium and the high-performance reinforced composites are compared with conventional aluminum alloys for subsonic vehicles. At high supersonic speeds, aerodynamic heating dictates use of high-temperature materials such as coated columbium, molybdenum, and TD nickel alloys. Fuselage, wing, tail, and engine nacelle components are individually considered for 5 representative subsonic and 3 supersonic configurations; 9 different material combinations are evaluated for the subsonic and 8 for the supersonic vehicles. Author (GRA)

N74-25561*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
DISPLAY REQUIREMENTS FOR THE FINAL APPROACH AND LANDING PHASE OF AN RPV MISSION
James C. Howard Apr. 1974 24 p refs
(NASA-TM-X-62346) Avail: NTIS HC $4.25 CSCL 01B

A two part investigation was conducted to determine the display requirements for the final approach and landing phase of a remotely piloted vehicle (RPV) mission, and to assess the relative merits of several possible display configurations. The objective of the first part of the investigation was to obtain subjective assessments of several display configurations, and to select the most promising display concepts for subsequent evaluation in terms of performance measures. A basic display consisting of a perspective image of terrain and runway, a horizon bar and an aircraft symbol was used, and guidance symbology was added to the basic displaying selected state variables. Initial results suggested that as guidance symbology is added to the basic display, pilot acceptance tends to increase. A point of diminishing returns is eventually reached, however, when additional information produces too much clutter, and makes it difficult for the pilot to process the displayed information.
Author

N74-21659*# Developmental Sciences, Inc., City of Industry, Calif. Aerospace Technology Div.
OBLIQUE WING REMOTELY PILOTED RESEARCH AIRCRAFT, VOLUME 1: DEVELOPMENT Final Report
Apr. 1974 144 p Original Contains Color Illustrations
(Contract NAS2-7211)
(NASA-CR-114723) Avail: NTIS HC $10.25 CSCL 01C

The NASA Ames/DSI oblique wing remotely piloted research aircraft is a highly unusual, variable remotely piloted vehicle whose configuration and capabilities are the result of certain initial design guidelines that, in terms of conventional aircraft structures and configurations, would be considered to be contradictory and unachievable. Accordingly, the novel design of the yawed wing RPV is at odds in many respects with conventional aircraft practice. Novelty, then, forms the first, unwritten, design guideline. This design is intended to move away from convention in g[illegible]y, structure, and materials. The specific guidelines followed [illegible]e design of the yawed wing RPV and a short discussion of the impact of each on the configuration of the vehicle are presented.
Author

COMPUTER SIMULATION OF RPV FLIGHT CHARACTERISTICS Final Technical Report, 1 Jan. - 29 Sep. 1973
Dixon Cleveland, Roger L. Barron, and Milford R. Derrick Mar. 1974 86 p refs
(Contract F33615-73-C-4055)
(AD-781079; AMRL-TR-73-119; Rept-676-FTR) Avail: NTIS CSCL 01/3

The report presents a set of equations of motion for remotely piloted vehicles. The equations are written in a form suitable for a real-time digital computer simulation. The simulation is intended to provide a test bed for evaluating alternative RPV control systems. A FORTRAN program for use on a Digital Equipment Corporation PDP-12 Computer is presented. Airframe parameter values are given for several flight conditions of an air-to-ground RPV, an air-to-air RPV and, a reconnaissance/EW RPV. Author (GRA)

N74-18671*# National Aeronautics and Space Administration. Flight Research Center, Edwards, Calif.
INITIAL RESULTS FROM FLIGHT TESTING A LARGE, REMOTELY PILOTED AIRPLANE MODEL
Euclid C. Holleman, comp. Mar. 1974 42 p refs
(NASA-TM-X-56024) Avail: NTIS HC $5.25 CSCL 01C

The first four flights of a remotely piloted airplane model showed that a flight envelope can be expanded rapidly and that hazardous flight tests can be conducted safely with good results. The flights also showed that aerodynamic data can be obtained quickly and effectively over a wide range of flight conditions, clear and useful impressions of handling and controllability of configurations can be obtained, and present computer and electronic technology provide the capability to close flight control loops on the ground, thus providing a new method of design and flight test for advanced aircraft. Author

N74-33465# Adaptronics, Inc., McLean, Va.
RPV/SELF-ORGANIZING CONTROL DEMONSTRATION SYSTEM. VOLUME 2: HARDWARE DESCRIPTION, SYSTEM OPERATION AND MAINTENANCE, AND RPV SIMULATION Final Technical Report, 1 Mar. 1972 - 31 Aug. 1973
Dixon Cleveland, James R. Binkley, and Roger L. Barron Feb 1974 209 p refs
(Contract F33615-72-C-1816; AF Proj. 7233)
(AD-781080; Rept-663-FTR; AMRL-TR-73-67) Avail: NTIS CSCL 01/3

Self-organizing control is a form of adaptive control in which the controller uses an incremental model of the plant and identifies parameters in this model by means of calculations based upon recent-term plant excitation and response histories. This report (in two volumes) presents the theoretical derivation of refinements in self-organizing control techniques yielding substantial reduction of sampling rates of self-organizing controllers and identification of magnitudes as well as polarities of plant gain parameters. Additionally, this report describes the implementation of self-organizing controller logic in the form of breadboard digital hardware, the equations and programs for a PDP-12 computer real-time simulation of remotely piloted vehicle flight with 6 degrees of freedom (without limitation to small aerodynamic angles), and design of a demonstration system. (Modified author abstract) GRA

N74-32458# Teledyne Ryan Aeronautical Co., San Diego, Calif.
RPV SHIPBOARD LAUNCH AND RECOVERY OPERATIONS STUDY Final Report
George C. Cota and Waldo V. Opfer, Jr. 28 Feb. 1974 266 p refs
(Contract N00014-73-C-0370; NR Proj. 212-221)
(AD-781712; TRA-29369-3) Avail: NTIS CSCL 01/2

Various methods for launch and recovery of remotely piloted vehicles (RPVs) from the decks of Naval ships were investigated. Eight RPV designs were developed to evaluate launch and recovery concepts from three classes of ships: the aircraft carrier, the sea control ship, and the ocean escort. Two basic RPV missions were assumed for the study: A 500-nautical-mile, high-low-high altitude, high subsonic penetration mission; and a medium-high altitude 14-hour endurance surveillance mission. (Modified author abstract) GRA

N74-18677*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
PRELIMINARY PERFORMANCE ESTIMATES OF A HIGHLY MANEUVERABLE REMOTELY PILOTED VEHICLE
Walter P. Nelms, Jr. and John A. Axelson Washington Feb. 1974 102 p refs
(NASA-TN-D-7551; A-5157) Avail: NTIS HC $4.50 CSCL 01C

A computerized synthesis program has been used to assess the effects of various vehicle and mission parameters on the performance of a highly maneuverable remotely piloted vehicle (RPV) for the air-to-air combat role. The configuration used in the study is a trapezoidal-wing and body concept, with forward-mounted stabilizing and control surfaces. The study mission consists of an outbound cruise, an acceleration phase, a series of subsonic and supersonic turns, and a return cruise. Performance is evaluated in terms of both the required vehicle weight to accomplish this mission and combat effectiveness as measured by turning and acceleration capability. The report describes the synthesis program, the mission, the vehicle, and the results of sensitivity and trade studies. Author

N75-12182# Test Group (6585th), Holloman AFB, N.Mex.
RADAR SIGNATURE MEASUREMENTS OF BQM-34A AND BQM-34F TARGET DRONES, VOLUME 1A Final Report
Jan. 1974 270 p
(AD-785219; AFSWC-TR-74-01-Vol-1A) Avail: NTIS CSCL 17/9

Monostatic measurements of the components of the target scattering matrix, monostatic and 30 degree bistatic measurements of target glint, as well as 10 and 20 degree bistatic measurements of target cross section were performed using vertical and horizontal antenna polarizations. Data were obtained from both the principal and crossed polarized components of the target return. Sixteen orientations of each vehicle were measured at a frequency of 5500 MHz. This report is published in three parts, each of which presents data acquired from both BQM-34 vehicles. Part A is limited to monostatic radar cross section and glint data. Part B presents radar cross section data acquired at bistatic angles of 10 and 20 degrees. Radar cross section and glint data acquired at a bistatic angle of 30 degrees are contained in Part C. (Modified author abstract) GRA

N74-19685# Adaptronics, Inc., McLean, Va.
RPV(REMOTELY PILOTED VEHICLE)/SELF-ORGANIZING CONTROL DEMONSTRATION SYSTEM. VOLUME 1: SOC EQUATION DEVELOPMENT, LOGIC CONFIGURATIONS, AND CONTROL MODES Final Technical Report, 1 Mar. 1972 - 31 Aug. 1973
D. Cleveland, Roger L. Barron, and Lewey O. Gilstrap, Jr. Wright-Patterson AFB, Ohio AMRL Dec. 1973 70 p refs (Contract F33615-72-C-1816; AF Proj. 7233)
(AD-773860; AMRL-TR-73-66-Vol-1) Avail: NTIS CSCL 12/1

Self-Organizing control is a form of adaptive control in which the controller uses an incremental model of the plant and identifies parameters in this model by means of calculations based upon recent-term plant excitation and response histories. The report presents the theoretical derivation of refinements in self-organizing control techniques yielding substantial reduction of sampling rates of self-organizing controllers and identification of magnitudes as well as polarities of plant gain parameters. Additionally, this report describes the implementation of self-organizing controller logic in the form of breadboard digital hardware. (Modified author abstract) GRA

N74-29522# Test Group (6585th), Holloman AFB, N.Mex.
RADAR CROSS SECTION MEASUREMENTS ON A BQM-34F TARGET DRONE, VOLUME 4A Final Report
Nov. 1973 279 p
(AD-777597; AFSWC-TR-72-20-Vol-4A) Avail: NTIS CSCL 17/9

The report documents radar cross section measurements of a BQM-34F target drone with active radar cross section augmentation. Part a presents the augmented cross section data acquired from the BQM-34F clean configuration with augmentation forward. GRA

N74-20683# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
AIR CUSHION LANDING SYSTEM PERFORMANCE ON A TENTH-SCALE MODEL JINDIVIK RPV M.S. Thesis
Philip M. Parker, Jr. Nov. 1973 74 p refs
(AD-774389; GAM/AE/73A-15) Avail: NTIS CSCL 01/3

Tests were conducted on an air cushion landing system ACLS installed on a tenth-scale model Jindivik RPV. The model has the correct Froude-scaled values of weight, center of gravity cg and moment of inertia about all three axes. The results of these tests were compared to the results of similar tests conducted on the ACLS of a full-scale model Jindivik. Static tests on the tenth-scale ACLS determined the heave stiffness to be 11 lb per in., the pitch stiffness to be .155 lb ft per deg (for a nose down moment) and the roll stiffness to be .0048 lb ft per deg. These values were within 60% of the full-scale values. Drop tests showed the maximum load at the cg of the model to vary between 2.2 g's at the scaled nominal landing rate of descent, to 5.4 g's at the maximum landing rate of descent. (Modified author abstract) GRA

N74-25717# Test Group (6585th), Holloman AFB, N.Mex.
RADAR CROSS SECTION AND ANTENNA GAIN MEASUREMENTS OF A BQM-34F TARGET DRONE Final Report
Oct. 1973 540 p
(AD-775983; AFSWC-TR-72-20-Vol-3A) Avail: NTIS CSCL 17/9

Static radar cross section data were acquired from a BQM-34F remotely piloted vehicle (RPV) at the U. S. Air Force Radar Target Scatter Facility, (RATSCAT), 6585th Test Group, Holloman AFB, New Mexico. The BQM-34F vehicle was configured to provide comparison data for several combinations of RCS and/or Infrared (IR) augmentation pods. Both monostatic and 10 degree bistatic data were obtained for eight vehicle roll angles and six vehicle pitch angles. Horizontal and vertical polarizations were used at a frequency of 9130 MHz. The report contains a description of the measurement conditions as well as reproductions of the raw and processed data acquired. (Modified author abstract) GRA

N73-30943*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
COMPUTERIZED PRELIMINARY DESIGN AT THE EARLY STAGES OF VEHICLE DEFINITION
Thomas J. Gregory Sep. 1973 35 p refs
(NASA-TM-X-62303) Avail: NTIS HC $3.75 CSCL 01C

Criteria for acceptance of early design information, modern methods of providing it, and suggestions for defining adequate levels of resources to accomplish the objectives of the activity are described. Specific examples of the most difficult type of early design studies, those requiring significant undeveloped technology, are used to discuss these points. The examples include design studies and cost estimates of liquid hydrogen fueled aircraft, oblique winged aircraft and remotely piloted vehicles. Author

N74-12737# Decision Science, Inc., San Diego, Calif.
INVESTIGATION OF PRINCIPLES OF CONTROL AND DISPLAY FOR RPVs Semiannual Technical Report, Feb. - Aug. 1973
Lawrence J. Fogel, Carl E. Englund, Michael L. Mout, and Thomas D. Hertz Aug. 1973 128 p refs
(Contract N00014-72-C-0196)
(AD-757414; DSI-ONR-TR-73-1) Avail: NTIS CSCL 01/3

The purpose of this investigation was to definitize principles of display and control suitable for remotely piloted vehicles of interest to the Navy. The immediate concern is directed toward RPV strike missions wherein an aircraft will be used to deliver conventional or laser-guided weapons to highly defined target, recover and seek further targets, then return to friendly territory. The report includes a brief discussion of the prior research conducted pertinent to this problem by Decision Science, Inc., a general research plan for the current investigation and preliminary statements regarding the first of a series of display control experiments. A bibliography is included as well as appendices which cover detailed materials used in support of this research effort. GRA

N73-24077# Decision Science, Inc., San Diego, Calif.
PRINCIPLES OF DISPLAY AND CONTROL DESIGN OF REMOTELY PILOTED VEHICLES Semiannual Technical Report
Lawrence J. Fogal, Robert S. Gill, Michael L. Mout, Douglas G. Hulett, and Carl E. Englund 14 Feb. 1973 156 p refs
(Contract N00014-72-C-0196; NR Proj. 196-119)
(AD-757761; SATR-2) Avail: NTIS CSCL 01/3

Review of potential RPV mission assignments and the peculiar problems of RPV flight control lead to a preliminary experiment wherein the performance of Navy attack pilots, model aircraft pilots, and engineer non-pilots was compared on a simulated scenario using eight different display/control configurations (inside-out vs. outside-in, attitude display, predictive vs. non-predictive attitude display and position vs. rate control stick). Navy pilots demonstrated significantly better performance; however, no significant difference was found between inside-out and outside-in display (although almost all subjects, including Navy pilots, preferred the outside-in presentation). Attitude prediction was not found to be of value, and position control stick was significantly superior to the conventional rate stick. The Embedded Figures Test appears to be a useful indicator of expected performance. Analysis revealed that additional information is required for manual flight control. Specific problems of sensor control, diagnosis of ECM impact, and usage of autopilot capability were identified. Suitable recommendations were identified. Suitable recommendations were made in this regard. Author (GRA)

N73-31985# San Diego Aircraft Engineering, Inc., Calif.
CONCEPTUAL DESIGN OF A AIR CUSHION LANDING SYSTEM FOR AN UNMANNED AIRCRAFT Final Report, 27 Mar. - 11 Aug. 1972
Henry B. McCudden, Paul D. Sorensen, George R. Lutz, William H. Stewart, and Donald R. Walborn 3 Jan. 1973 126 p refs
(Contract F33615-72-C-1769; AF Proj. 1369)
(AD-764774; SAE-72-031; AFFDL-TR-72-155) Avail: NTIS CSCL 01/3

The problems associated with existing recovery systems include difficulty in mid-air retrieval of RPV's in excess of 1500 lbs; high operations and support costs of parachutes, recovery helicopters, other aircraft and their crews; long recycle time; paving quality requirements for wheeled or skid type landing gear; and frequent damage of RPV's recovered by parachute/attenuation bag or parachute/mid-air recovery systems. Accordingly, this preliminary design study report describes an air cushion landing system (ACLS) applied to the 3,000 lb Jindivik Mk 3A unmanned aircraft. The ACLS is stowed for cruise flight in a clean aerodynamic fairing on the underfuselage, resulting in a minimum performance degradation. For recovery, hinged clam-shell type doors are unlatched, and open, permitting inflation/deployment of an inelastic type elongated toroid-shaped trunk. The trunk is inflated and blown with bleed air tapped off an existing port on the Jindivik's Viper Mk 201 engine. After landing, the aircraft is placed on a fixture and the trunk is manually restowed in the fairing. (Modified author abstract) GRA

N73-21060# RAND Corp., Santa Monica, Calif.
LOW COST TACTICAL RPVs
R. H. Jacobson Sep. 1972 10 p
(P-4902) Avail: NTIS HC $3.00

The development of low cost remotely piloted vehicles is discussed. The emphasis is placed on development of an unconstrained innovative approach in establishing the logistic and maintenance characteristics which can significantly influence the overall design of remotely piloted vehicles and the required ground support equipment. Methods in which the costs of unmanned flying vehicles can be reduced are proposed. The application of automated production procedures and the use of composite materials are recommended. Author

N73-24079# Bell Aerospace Co., Buffalo, N.Y.
A STUDY OF AIR CUSHION LANDING SYSTEMS FOR RECOVERY OF UNMANNED AIRCRAFT
John M. Ryken Wright-Patterson AFB, Ohio AFFDL Jul. 1972 141 p refs
(Contract F33615-72-C-1175; AF Proj. 1369)
(AD-758789; AFFDL-TR-72-87) Avail: NTIS CSCL 06/7

The report presents results of a concept feasibility and formulation study of Air Cushion Landing Systems for recovery of unmanned aircraft (Remotely Piloted Vehicles). A modified Ryan Model 147G drone or special purpose aircraft was investigated for possible use in a low cost flight test demonstration of air cushion landing gear concepts on an existing unmanned aircraft. Recovery by horizontal landing on an air cushion landing system is compared with recovery with a mid-air recovery system.
Author (GRA)

N72-21817*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
PERFORMANCE AND CONTROL STUDY OF A LOW-PRESSURE-RATIO TURBOJET ENGINE FOR A DRONE AIRCRAFT
Kurt Seldner, Lucille C. Geyser, Harold Gold, Darrel Walker, and Gary Burgner Apr. 1972 55 p refs
(NASA-TM-X-2537; E-6688) Avail: NTIS CSCL 21E

The results of analog and digital computer studies of a low-pressure-ratio turbojet engine system for use in a drone vehicle are presented. The turbojet engine consists of a four-stage axial compressor, single-stage turbine, and a fixed area exhaust nozzle. Three simplified fuel schedules and a generalized parameter fuel control for the engine system are presented and evaluated. The evaluation is based on the performance of each schedule or control during engine acceleration from a windmill start at Mach 0.8 and 6100 meters to 100 percent corrected speed. It was found that, because of the higher acceleration margin permitted by the control, the generalized parameter control exhibited the best dynamic performance. Author

N74-12723# Research Inst. of National Defence, Stockholm (Sweden).

REMOTE CONTROL OF AIRCRAFT AND WEAPON SYSTEM USING A NEW METHOD [FJARRSTYRNING AV FLYGPLAN OCH VAPENSYSTEM ENLIGT NY METOD]

Curt Haglund Feb. 1972 16 p In SWEDISH

(FOA-2-A-2553-E4) Avail: NTIS HC $3.00

Remote controlled aircraft can now be maneuvered in a very advanced manner by use of a system for remote sensing and data transference in real time of visual and other information from and to the aircraft. This information in combination with a system for remote operation, makes it possible for a pilot to maneuver the aircraft from a guiding station as if he was in the aircraft. In the U.S.A. this aircraft is called a remotely piloted vehicle (RPV). Development work has been going on for some years and tests with such aircraft have been made. The method can also be used for remote manning of other weapon systems. Author

N70-25828*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

EFFECTS OF ADDITIONAL REVISIONS ON THE AERODYNAMIC CHARACTERISTICS OF A TARGET DRONE VEHICLE AT MACH NUMBERS FROM 1.70 TO 4.63. COORD NO. AF-AM-827

A. B. Blair, Jr. and Dorothy H. Tudor Washington Feb. 1970 168 p refs

(NASA-TM-X-1961) Avail: CFSTI CSCL 01A

A wind-tunnel investigation to determine the effects of several modifications on the supersonic aerodynamic characteristics of a 1/4-scale target drone vehicle is reported. The investigation was conducted at Mach numbers from 1.70 to 4.63, at angles of attack from about -4 deg to 16 deg, at angles of sideslip from about -4 deg to 6 deg, and at a Reynolds number of 9,380,000 based on model length. Results of this investigation indicated that the model with either wing or with a wing-canard combination was longitudinally stable about the selected moment center. Both the large and the small canards were effective trim devices, and the trim power appeared to be a linear function of canard planform area. The model with large vertical fins was directionally stable and had positive effective dihedral throughout the angle-of-attack and Mach number ranges; however, reducing the size of the vertical fins led to a large decrease in directional stability throughout the angle-of-attack and Mach number ranges. The ailerons were effective in producing rolling moment throughout the angle-of-attack and Mach number ranges, although there was a significant decrease in effectiveness with increases in Mach number. Aileron deflection generally produced an adverse yawing moment which tended to increase with angle of attack. Author

N69-33565# Army Materiel Command, Washington, D.C. Systems and Cost Analysis Div.

A CONCEPTUAL ANALYSIS SURVEILLANCE AND ARMED AERIAL VEHICLES (MANNED AND UNMANNED)

William J. Tropf, Stephen J. Lanigan, and W. Allen Gilchrist, Jr. Apr. 1969 33 p

(AD-687295; TR 69-15) Avail: CFSTI CSCL 15/7

This study is a conceptual analysis of drones in the aerial surveillance and armed aerial vehicle role. Generic manned and unmanned aerial subsystems are compared against a generalized mission to address the question: what happens if we have drones; and why we have drones, on a first level basis. Further discussion includes resource requirements and certain more abstract considerations such as the value of manned space probes and how the emphasis on manned spacecraft vs a corresponding emphasis for unmanned aerial vehicles can be reconciled. The major findings of the authors are threefold. Drones presently offer no capability which could not conceivably be achieved with a manned system, but certain missions may be better accomplished by unmanned systems. The question then, is a matter of degree rather than additional capability. Secondly, under certain conditions and for specific types of missions drones may represent a more cost effective choice in the current time frame; and these cases should become more pronounced as the state-of-the-art progresses. Finally, the most significant advantage of having drones is that along with manned aircraft they represent a system offering considerable flexibility of choice to the field commander. Author (TAB)

N64-16469 David Taylor Model Basin, Washington, D.C. Aerodynamics Lab.

WIND TUNNEL INVESTIGATION OF LAUNCH TRAJECTORIES OF THE BEECH XKD2B-1 TARGET DRONE WHEN LAUNCHED FROM THE F3H-2 AIRPLANE

Henry S. Ozarko Dec. 1963 106 p refs

(DTMB-AERO-993; AD-430438)

An investigation was performed in the 7- by 10-foot Transonic Wind Tunnel to predict the trajectory characteristics of the Beech XKD2B-1 target drone following launch from the F3H-2 airplane. A series of 23 trajectories were predicted for launch conditions at several Mach numbers and altitudes with various pylon configurations. Aileron response was assumed to be in accordance with drone autopilot operation, except for one trajectory in each group, which was also computed for ailerons fixed. Author

X70-17501# Army Test and Evaluation Command, Aberdeen Proving Ground, Md.
DRONE AIRCRAFT Final Report
25 Mar. 1970 12 p refs
(AD-871331; MTP-7-2-040) CSCL 1/3 Unclassified report

NOTICE: Available to U.S. Government Agencies and Their Contractors Only

The report describes test methods and techniques for evaluating the technical performance and characteristics of drone aircraft. The evaluation is related to criteria expressed in applicable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), Technical Characteristics (TC), or other appropriate design requirements and specifications. Author (TAB)

X69-19303# Naval Air Facility, China Lake, Calif.
SYNCHRONOUS COUNTER FREQUENCY CODING FOR REMOTE CONTROL Development Report, Apr. 1967 Jul. 1968
David W. Kermode Jul. 1969 26 p refs
(AD-856824L; NAF-TP-183-69-1) CSCL 1/3
Unclassified report

NOTICE: Available to U.S. Government Agencies Only

The report describes a system of coding modulation frequency pulse groups with synchronous electronic counters. The system provides security to remote command functions, and can be expanded to control several drone aircraft simultaneously. Author (TAB)

X70-12284# Applied Systems Corp., Rockville, Md.
UNCONVENTIONAL AIRCRAFT POWERPLANTS CATALOG
J. I. Mc Guire, Jr. and R. D. Doorley Aug. 1969 136 p
(Contract N00019-69-C-0391)
(AD-862249) CSCL 21/7 Unclassified report

NOTICE: Available to U.S. Government Agencies and Their Contractors Only

The catalog represents a limited attempt to identify and describe new powerplant concepts for light aircraft, helicopters, and drones. Emphasis has been placed on designs suitable for 50 to 500 h.p. class vehicles, and on their general merits relative to the gas turbine. Author (TAB)

X70-12842# Armament Development and Test Center, Eglin AFB, Fla.
DAPHNE FEASIBILITY TEST Final Report
Randall V. Gressang Dec. 1969 91 p refs
(ARPA Order 1493)
(AD-863454; ADTC-TR-69-219) CSCL 17/7
Unclassified report

NOTICE: Available to U.S. Government Agencies and Their Contractors Only

The initial and repeatable accuracies of the DAPHNE (Drone Aircraft Positioning, Homing, and Navigation Equipment) system were determined by recording system outputs with the two parts of the system established at known locations, comparing the indicated DAPHNE position with true position, and performing statistical calculations upon the DAPHNE system outputs. A comparison of DAPHNE performance was made with that to be expected from conventional LORAN-C. The DAPHNE system tested provided DRMS circles of repeatable accuracy from 107 meters to 295 meters, depending on the signal-to-noise ratio present at the DAPHNE correlator. Noise introduced by the data link used by the system had great effect upon repeatable accuracy. The DAPHNE system tested did not perform as well as two conventional LORAN-C receivers operating in a differential LORAN-C mode would be expected to perform. Author (TAB)

X69-19834# Northrop Corp., Newbury Park, Calif. Ventura Div.
QUALIFICATION TEST REPORT FOR FUEL PUMP SCD 58561 Final Report, Nov. 1967 - Jun. 1968
James A. Daniel 1 Jun. 1968 136 p
(Contract N00019-67-C-0456)
(AD-858504L; IDEP-575.40.30.60-SE-01; NVR-6253) CSCL 13/11 Unclassified report

This report presents the results of an evaluation of a fuel pump for use in the MQM-74A Drone application. The following tests were performed: Temperature-Altitude; Vibration; Shock; Acceleration; Electromagnetic interference; Explosion. TAB

X69-14730# Picatinny Arsenal, Dover, N. J. Ammunition Engineering Directorate.
AN/USD-5 XE-2 DRONE BOOSTER (U)
Arthus R. Lusardi Jan. 1969 73 p refs
(AD-395742; PA-TR-3848) CSCL 1/3
Confidential report GP-4

NOTICE: Available to U.S. Government Agencies and Their Contractors Only

The Ammunition Engineering Directorates Solid Rocket Propulsion Laboratory was assigned to design, develop and test a booster for the AN/USD-5 XE-2 Drone in accordance with Fairchild Equipment Specification M-804 from the U.S. Army Signal Research and Development Laboratories at Fort Monmouth. A testing program was undertaken and the booster satisfactorily performed in all tests. Boosters for 16 more dynamic flight tests were in various stages of fabrication when the overall Drone development program was cancelled. Uncl. Author (TAB)

X69-17308# Air Force Systems Command, Eglin AFB, Fla. Armament Development and Test Center.
NITE GAZELLE, PHASE 1 (U) Final Report, 27 Nov. 1968 - 31 Jan. 1969
Gary T. Smith May 1969 96 p refs
(AD-502149; ADTC-TR-69-57) CSCL 1/3
Confidential report GP-3

NOTICE: Available to U.S. Government Agencies and Their Contractors Only

A QH-50D drone helicopter with various low light level television sensors was tested to determine the systems ability in detecting, recognizing, and identifying tactical targets, navigating to given positions, and tracking and aiming at moving and stationary targets. The covertness of the system to human detection was also evaluated. Conf. TAB

X65-19616# Motorola, Inc., Scottsdale, Ariz. Military Electronics Div.
NAVIGATION, GUIDANCE AND CONTROL SYSTEM FOR DRONE AIRCRAFT, EVALUATION FLIGHT TEST PROGRAM (U) Final Engineering Report, 1 Sep. 1961-24 Jul. 1964
N. E. Welter [1964] 93 p
(Contract DA-36 039-SC-87352)
(AD-361851) Confidential report GP-3

NOTICE: Available to U.S. Government Agencies and Their Contractors Only

Discussed are methods and results of the flight test program for the evaluation of a feasibility model of the navigation, guidance, and control system for the Drone aircraft. This system utilizes information from a low frequency radio source and a doppler velocity sensor to provide the control information. It uses pseudo-noise coded transmission and coherent detection to eliminate the effects of skywave, and to provide security against enemy electronic countermeasures. Data and tests indicated that the system functions as predicted by analysis, is capable of operation in the presence of enemy countermeasures, and exploits the input data to the limits which are imposed by nature. System error is primarily due to the natural limitations which exist in the propagation of the LF signals. Conf.** G.G.

[redacted] UNCLASSIFIED

X65-17609# Naval Ordnance Test Station, China Lake, Calif.
THEORETICAL STUDIES OF LONG-DURATION ENGINES (U) Technical Publications, 1 Feb.–3 Oct. 1961
H. M. Platzek and S. S. Haseyama Nov. 1964 98 p refs
(NAVWEPS-7817; NOTS-TP-2824; AD-360261)
Confidential report GP-4

A series of theoretical studies was made of possible engines for propelling a supersonic target drone, with thrusts varying from 150 to 250 lb, at maintained speeds approximating Mach 3, for durations of 10 to 20 min, and at altitudes of 80,000 to 100,000 ft. The engine diameter was not to exceed 16 in and its weight, 1,200 lb. Results of the studies show that, for rapid development of an effective prototype, a liquid-fueled ramjet appears to be the most promising and least expensive of engines that meet the requirements. However, ramjet operating altitude is limited to about 90,000 ft. With a development time of about 3 years allowed, and no strict limit on the cost of a prototype, the liquid bipropellant rocket will make the most satisfactory engine, and the operating altitude is unlimited. Author Conf.

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