Central Intelligence Agency

Washington, D.C. 20505

16 December 2019

Mr. John Greenewald, Jr.
The Black Vault
27305 West Live Oak Road
Suite #1203
Castaic, CA 91384

Reference: F-2013-02278

Dear Mr. Greenewald:

This is a final response to your 26 July 2013 Freedom of Information Act (FOIA) request for **all records pertaining to the insectothopter**. We processed your request in accordance with the FOIA, 5 U.S.C. § 552, as amended, and the CIA Information Act, 50 U.S.C. § 3141, as amended.

We completed a thorough search for records responsive to your request and located three documents that we determined can be released in their entirety. Copies of the documents are enclosed at Tab A. We also determined that three documents can be released in segregable form with deletions made on the basis of FOIA exemptions (b)(1) and/or (b)(3). Copies of the documents are enclosed at Tab B. Exemption (b)(3) pertains to information exempt from disclosure by statute. In this case, the relevant statutes are Section 6 of the Central Intelligence Agency Act of 1949, 50 U.S.C. § 3507, as amended, and Section 102A(i)(l) of the National Security Act of 1947, 50 U.S.C. 3024(i)(1), as amended.

As the CIA Information and Privacy Coordinator, I am the CIA official responsible for this determination. You have the right to appeal this response to the Agency Release Panel, in my care, within 90 days from the date of this letter. Please include the basis of your appeal.

Please be advised that you may seek dispute resolution services from the CIA's FOIA Public Liaison or from the Office of Government Information Services (OGIS) of the National Archives and Records Administration. OGIS offers mediation services to help resolve disputes between FOIA requesters and Federal agencies. Please note, contacting CIA's FOIA Public Liaison or OGIS does not affect your right to pursue an administrative appeal.

To contact **CIA** directly or to appeal the CIA's response to the Agency Release Panel:	To contact the Office of **Government Information Services (OGIS)** for mediation or with questions:
Central Intelligence Agency Washington, DC 20505 Information and Privacy Coordinator (703) 613-3007 (Fax) (703) 613-1287 (CIA FOIA Public Liaison / FOIA Hotline)	Office of Government Information Services National Archives and Records Administration 8601 Adelphi Road – OGIS College Park, MD 20740-6001 (202) 741-5770 (877) 864-6448 (202) 741-5769 (Fax) ogis@nara.gov

If you have any questions regarding our response, you may contact the CIA's FOIA Hotline at (703) 613-1287.

Sincerely,

Mark Lilly
Information and Privacy Coordinator

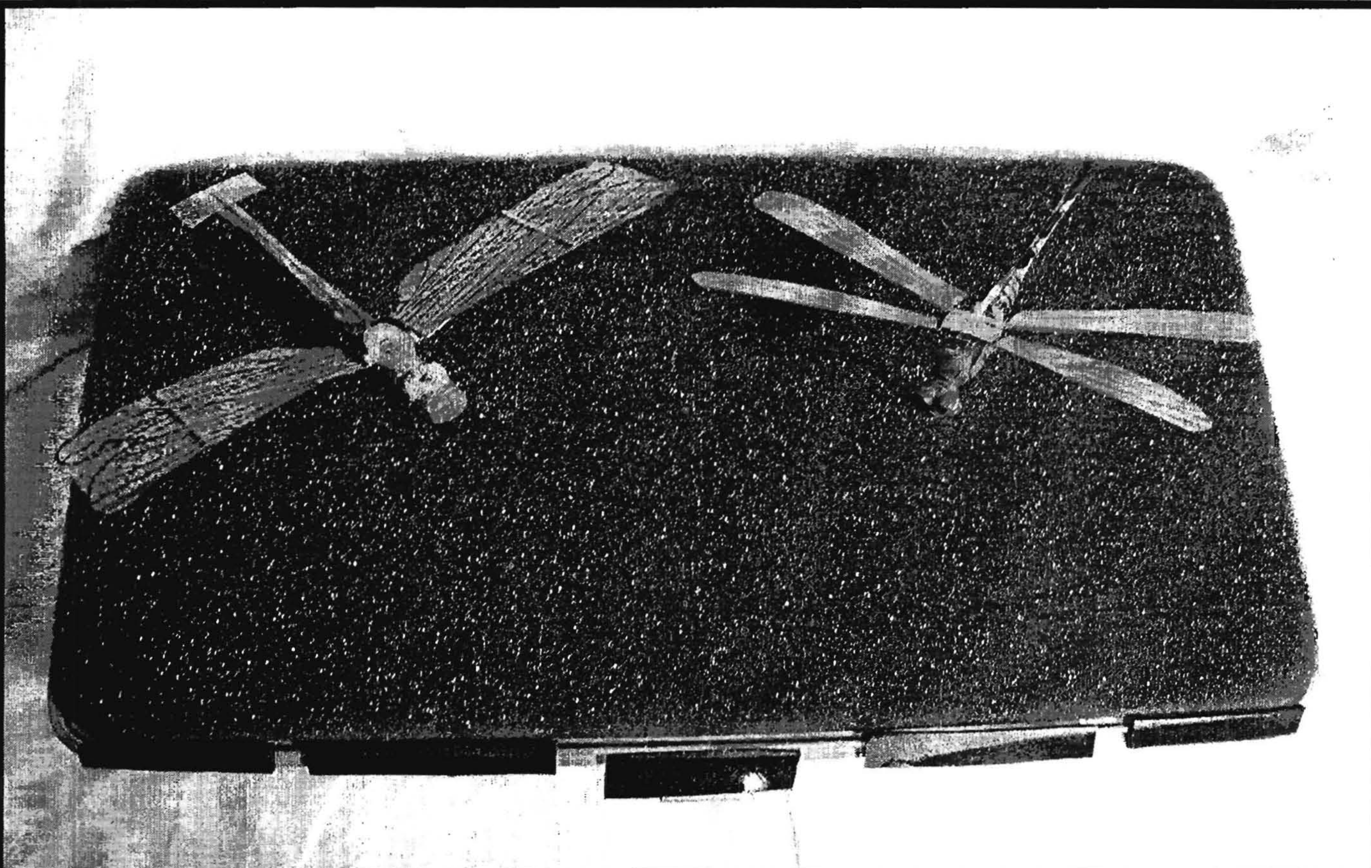
Enclosures

TAB A

UNCLASSIFIED

CIA MUSEUM

Insectothopter (Prototype(L), Operational(R)

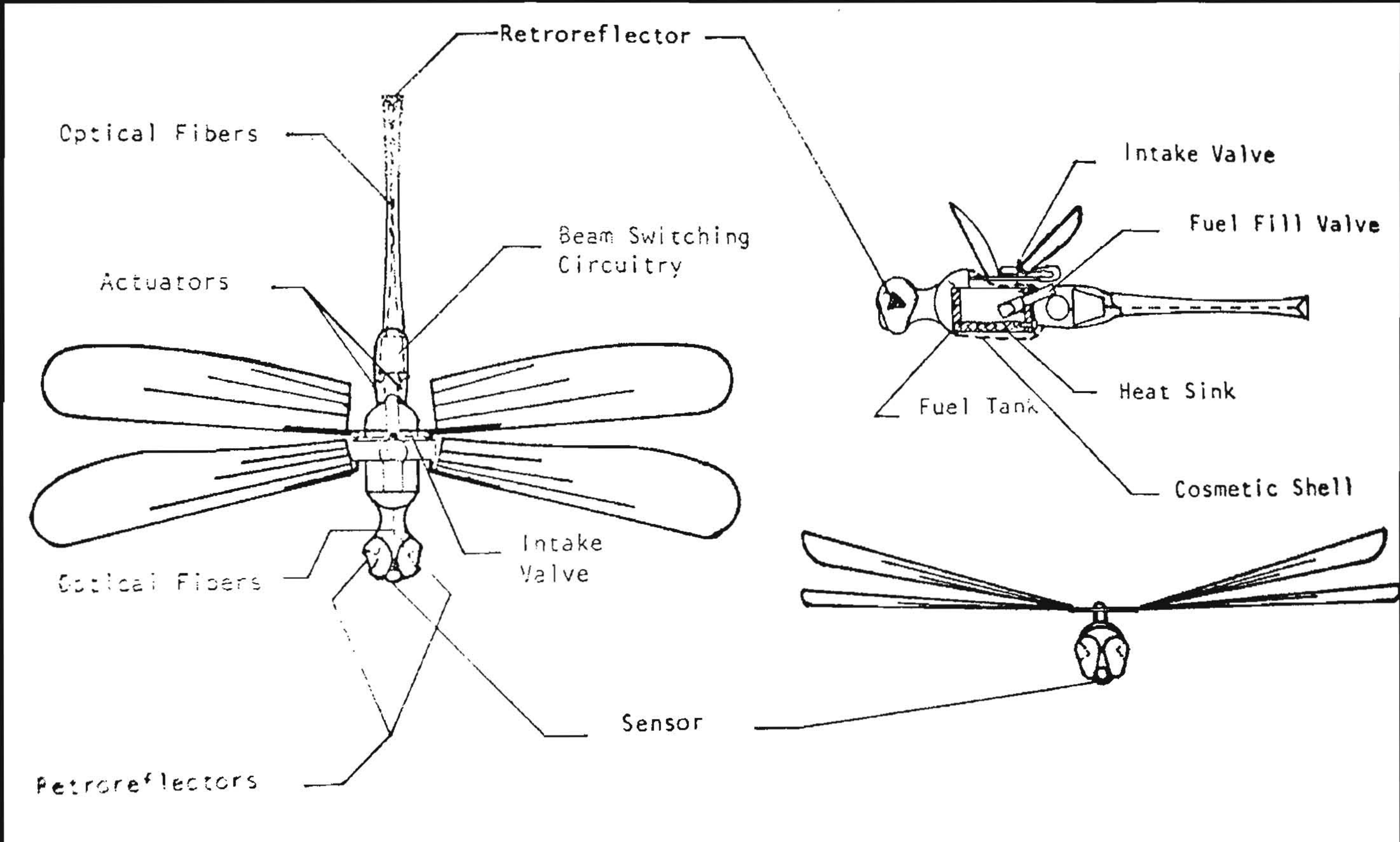


UNCLASSIFIED

UNCLASSIFIED

MUSEUM

Insectothopter Drawing



UNCLASSIFIED

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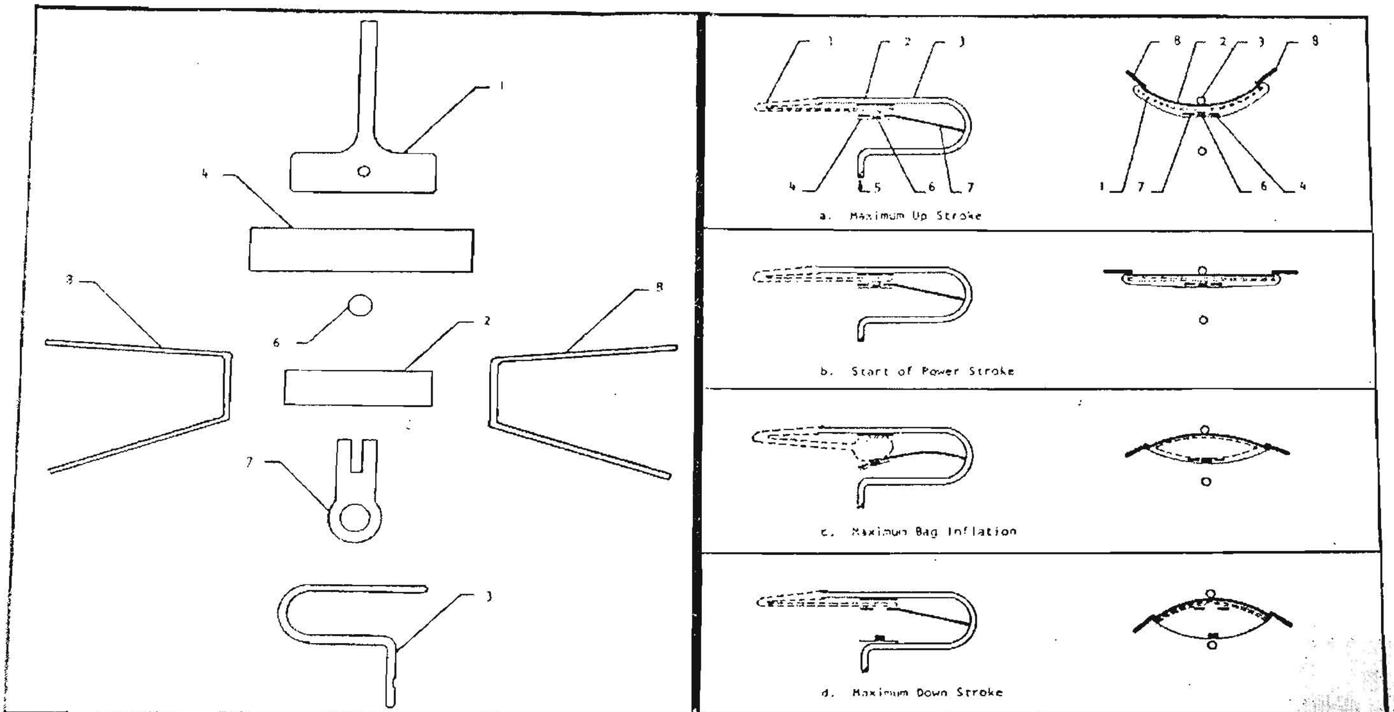
CIA MUSEUM

Insectothopter Engine Parts



1. Power [illegible]
2. [illegible]
3. [illegible] Line
4. [illegible]
5. Fuel Entry
6. Exhaust Valve Seal
7. Depressor Spring
8. Wing Attachment Spar

UNCLASSIFIED

TITLE: Insectithopter

CONTRACTOR: Advanced Technology Center

COST: $105,376

ORN NO. [redacted]

MONTH TO LET: September 1972

(b)(3)

SUB-CATEGORY/ELEMENT: Collection Systems/Emplacement Systems

PROJECT: Long Range/Concept Analysis

DESCRIPTION: This is a follow-on program to demonstrate control and communication feasibility of the insectithopter. Under this program, free-flight tests and payload/endurance capabilities will be conducted, and communication, navigation, and propulsion technologies developed.

BACKGROUND: The insectithopter has been tested in free-flight and wind tunnel tests. Concepts for using the "ROME" laser system for command, control, and data link look promising but no specific experiments have been conducted. It is proposed that this system be interfaced with the vehicle and flight tested to at least 300 feet to establish total system feasibility. The "ROME" laser system uses a very small retro-modulator as one mirror of a long laser cavity.

SECRET

COORDINATION: [redacted]

Contract # [redacted]

(b)(3)

TYPE OF WORK: Advanced Development

Comp. Date: 11/13/73

FIELD OF WORK: Electronics

COMPLETED

AND HISTORY

IDEA	PROP. SOLICITED	PROP. IN H[redacted]	[redacted]
ISSUE DATE	FAN NO.	DIV[redacted]	
9/7/72	[redacted]	Donald Reiser	Charles N. Adkins [redacted]

(b)(3)

TITLE	ORN NO.	CONTRACTOR	COST
Insectithopter K-13	[redacted]	Advanced Tech.Cen.	$105,376

(b)(3)

ORD-1531-74

4 April 1974

PROJECT HISTORY

Title: Insectithopter
Contractor: Advanced Technology Center
Amount: $105,376

ORN: [redacted] (b)(3)

1. Intelligence Objective: To provide a clandestine insect-like (dragonfly) vehicle capable of being directed to a specific target at least 100 meters distant for the purpose of emplacing an audio surveillance device (optical microphone). At the outset of this program, both the aerodynamic and propulsive feasibility had been demonstrated by flight tests during a phase zero effort of $40,000. In addition, the proposed method of providing tracking and guidance (the "ROME Laser" system) was a proven operational concept. On the other hand, the optical microphone had been demonstrated only in breadboard form and further development would be required to meet size and weight requirements.

2. Original Project Goal: Demonstrate system feasibility by:

   a. Building a ROME laser system to track the vehicle and provide at least one channel of control signals to the vehicle. [redacted] (b)(3)

EXEMPT FROM GENERAL DECLASSIFICATION
OF E. O. 11652, EXEMPTION CATEGORY:
§ 5B(1), (2), (3) or (4) (circle one or more)
AUTOMATICALLY DECLASSIFIED ON
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(unless impossible, insert date or event)

b. Designing and implementing at least a one-axis control system (yaw) which will steer the vehicle upon command.

c. Building a vehicle with sufficient performance to carry the on-board control system and a 0.1-gram payload.

d. Demonstrating system performance by conducting flight tests.

3. Modifications of Project Goal: None.

4. Accomplishments of This Effort Relative to Project Goal and Contribution Toward Intelligence Objective: Even though the project goals were accomplished, additional work must be done to meet the intelligence objective. These include:

a. Provide an additional channel (pitch) of control in both the laser and on-board guidance system.

b. Demonstrate two-channel controlled powered flight outdoors in varying wind conditions to determine emplacement accuracy.

c. Develop further the optical microphone payload to meet weight and size requirements.

The feasibility of a controlled insectithopter vehicle with limited operational capability has been investigated and all program goals to this point have been achieved, either by operational demonstration or through analysis of experimental results. Basic vehicle technology has been developed to provide a vehicle capable of flying at 0.8 g gross weight with flapping wing propulsion alone and at 1.0 g with jet propulsion and cosmetic wing flapping. The actual empty weight is nominally 0.4 g compared to a target weight of 0.6 g. Performance measurements indicate range and endurance capabilities of 200 meters and 60 seconds with jet propulsion and cosmetic flapping for 1.0 g launch weight.

Satisfactory stability and control characteristics were analytically determined and experimentally demonstrated in wind tunnel and free flight tests. Heading error with controls fixed for both straight and turning unpowered flight was repeatably less than ± 50 mils.

A tracking, guidance, and control system was developed and demonstrated for single-channel directional control of the vehicle. The system includes a ROME laser and telescope assembly which has been demonstrated at ranges in excess of 140 meters with a 1 mm target. Transmitted power has been measured in excess of 1.2 watts with a field of view of 80 mils. Tracking was demonstrated up to 140 meter range with a moving target on both indoor and outdoor ranges in various sunlight and wind conditions. Designs for more sophisticated multi-channel systems have been developed and analyzed.

A thermo-pneumatic, ROME-powered rudder actuator was developed and demonstrated at vehicle scale and weight in wind tunnel and flight tests, meeting the control power and response time requirements for directional control of the vehicle.

Wind tunnel and flight test experiments have demonstrated the feasibility of the complete integrated system. Controlled flight was repeatedly demonstrated with a gliding vehicle and the ROME laser on an indoor flight range. Limited powered flight tests were conducted outdoors with fixed controls in winds up to 10 mph with a heading error less than ± 100 mils.

The ultimate demonstration of controlled powered flight has not yet been achieved. Considering the extensive burden placed on the laser operator in the tracking procedure and the additional directional perturbation effects experienced with powered flights, it was concluded that insufficient time remained in the contract period to satisfactorily develop techniques for meaningful powered controlled flights.

5. Evaluation of Project and Contractor: Technically, the project must be evaluated as excellent. However, there appears to be a decreasing lack of support from potential users, and the additional research funds required to meet the final intelligence objective is larger than expected.

The contractor's performance in solving the most difficult and unique problems associated with this unusual program can only receive the highest acclaim.

6. Discussion:

a. Origin of Project. An expressed need for a remote audio emplacement system.

b. Technical Approach. To use an indigenous insect-like vehicle.

c. Personnel and Funding Considerations. Key personnel (research scientists) at ATC had conducted tests on live insects, and the ROME laser technology is proprietary to LTV, which owns 80 percent of ATC. Initially, $40,000 was placed at ATC to demonstrate aerodynamic and propulsive feasibility. The effort described here was for $105,376.

d. Problems Encountered and Solutions. The entire program was a composite of unique problem-solving. In the area of aerodynamics, increased wing stiffness and performance was required to carry the additional payload and control system weight. This was accomplished by incorporating boron fiber elements in the wing. Additional performance was obtained by venting the exhaust aft to provide jet thrust. A larger engine was required to provide increased power to the wings. With the larger engine intake porting, lithium nitrate crystals (the propellant) were being ingested into the engine. This problem was solved by incorporating a thin-walled container for the lithium nitrate inside the fuel tank. Structural and weight problems regarding the airframe and on-board control systems were continually being solved throughout the program.

e. <u>Reasons for Failure or Success</u>. The ability of the contractor to try new materials, build an inexpensive wind tunnel, and conduct many flight tests in a fly it-fix it iterative approach to problem-solving contributed in large measure to the technical success of the program.

f. <u>Recommendations for Further R&D and Disposition of Final Product</u>. Though further development is required to provide for pitch control, emplacement accuracy, and the flight weight optical microphone, the concept feasibility is established. It is recommended that this additional work be done if and when a specific user/mission can be defined so that user and mission specifications can be addressed. To date, there is no final product except general feasibility of being able to achieve the intelligence objectives.

7. Coordination: Various briefings have been given, including OTS who would be responsible for user selection. As of this time, no user and/or mission has been found. The final report has been given to OTS.

Charles N. Adkins
Project Officer

INSECTITHOPTER

SHORT RANGE--AIR

(C. Adkins, ORD)

Description:

This vehicle is a fluttering wing, miniature drone, which has limited flight characteristics. The design is intended to be insect-like in appearance when casually observed.

Status:

Engineering development of the vehicle subsystem primarily. Approximately $100K has been funded through FY73.

I. Environmental Consideration:

a. WEATHER

Wind must be 10 fps or less since cruise speed is about 15 fps. Range will be reduced by the ratio of head wind speed to cruise speed. Winds below 10 fps will not appreciably affect structures or stability. Cold weather operations would not look realistic. Fog or smoke will affect Nav/Commo.

b. TOPOGRAPHY

Only local topographic extremes expected over 200 meter distances.

c. DEMOGRAPHY

High concentration of people and man-made objects. Detection is improbable at distances larger than several feet as being anything other than an insect.

SECRET

d. DETECTION

Detection is improbable at distances larger than several feet as being anything other than an insect from both acoustic and visual observations. This obviates cold weather operations.

e. DEFENSIVE SYSTEMS

No known defensive systems at distances larger than several feet.

f. MISSION PLANNING

This depends greatly on specific mission and could vary [redacted] (b)(1) (b)(3)

II. Systems Requirements:

a. VEHICLE

Plausibly disguised to observers as indigenous life.

b. GUIDANCE AND CONTROL

LOS command.

c. COMMO

LASER IR. LASER does not lase if beam is interrupted.

d. NAVIGATION

Vidicon display of vehicle azimuth and elevation.

d. MISSION CONTROL

Operation from [redacted] within 200 meters of target. (b)(1) (b)(3)

f. MISSION PLANNING

Comparable to [redacted] audio ops. (b)(1) (b)(3)

III. Surface Coverage

a. RANGE

Up to about 200 meters.

b. LAUNCH AND RECOVERY

From rented space through window or roof or from auto, etc.

c. GEOGRAPHIC COVERAGE

Any place or time of year indigenous to insect.

d. TARGETS

Any line-of-sight target within 200 meters of launch.

IV. Payloads:

Optical microphone has been tested. This would be used for audio surveillance and could be a payload drop with vehicle returning to launch point or elsewhere. Payload weight is restricted to a few tenths of a gram.

Personal recollections

Vehicle Platforms in the Office of Research and Development

Charles N. Adkins

The day Sputnik went into orbit in 1957, I was interviewing with Melpar, Inc., primarily an electronics firm, in Falls Church, Virginia. They needed a physicist to work on a contract [redacted] This led to a published article in the early 1960s and several contracts with the Agency's newly formed Office of Research and Development (ORD), located in the Ames Building in Rosslyn, Virginia.

(b)(1)
(b)(3)

In 1966 I joined ORD to work on the Aquiline project. This was to be a small unmanned vehicle, shaped like a bird, that would augment the U-2 as a reconnaissance platform. Its major asset supposedly was its low cost. As a contractor, I had briefed Bud Wheelon, the Deputy Director for Science and Technology, on several occasions, and I asked him how the U-2 was developed. He said, "It was very simple, we found the best aerodynamicist in the business, Kelly Johnson, and told him to build the most reliable vehicle that would get our sensors over the target and home again." Unfortunately, this was not to be the strategy for developing Aquiline.

ORD was an ad hoc group with no official charter. Its primary assets were a few dynamic individuals with vivid imaginations. Two such people were Dave Christ, the division chief and driving force behind Aquiline, and Don Reiser, his deputy. Many were new employees like Frank Briglia, hired as project manager for Aquiline, and C. V. Noyes, who, as a potential contractor, wrote such a good proposal that Dave decided it would be cheaper to hire him.

Dave Christ was good at identifying advanced concepts and a master at selling to upper management. Don Reiser could milk the most from technical people and contractors. His efforts in low-voltage transistors and micropower electronics were among the first significant successes in ORD.

The third important member of this team was a consultant named [redacted] A mathematician by nature and an electronics engineer by trade, [redacted] (b)(3)

(b)(3)

My addition to this team was to fill the gap in aerodynamics and to feed Dave's dream of a family of vehicle platforms that would span the next 20 years. The first two were Aquiline and its little-known successor, Axillary.

The Aquiline Project

Dave Christ delighted in describing his first meeting with Douglas Aircraft: "I told them we wanted an unmanned aircraft that would fly over 1,000 miles, have an autopilot with complete on-board navigation, a payload of a few pounds for taking pictures or collecting intelligence of one kind or another, a wing span of only 10 feet or so, and look like a bird."

The first challenge was to construct an initial operational capability (IOC) vehicle that looked like a large model airplane. The first attempts to fly the IOC ended in crashes, and I mentioned to Frank Briglia that the

Douglas team knew nothing of the sport of making and flying radio control (RC) aircraft and that perhaps they needed such a person on the team.

Douglas did try to fly model airplanes, but their test pilots had little skill in RC flying and more crashes followed. Frank concluded that the solution was to forego further RC tests and to push ahead on the autopilot development that he felt would avert further problems of human error. He wanted the next flight to be fully automatic.

(b)(3) As the flight test grew near, Don, [redacted] and I left for the test site at China Lake, California. The facilities, the flight planning, and the previous test results were impressive, and the Douglas team was confident that a successful flight would vindicate the past failures and large costs that had plagued the project.

The countdown the next day seemed to take forever. Finally, the engine was started, and the vehicle's umbilical cable was disconnected from the site trailer. Once the vehicle was launched, it passed over the edge of a cliff, rotated 90°, nose down, and disappeared from view. Those who walked to the cliff's edge knew what they would see on the rocks below.

Back at Ames, we received the call from Douglas explaining that the longitudinal accelerometer had experienced high acceleration as the vehicle traveled down the launcher. This caused the autopilot to believe the nose was pointed up, and the control surfaces were in the nose down position as it passed over the edge of the cliff.

Don Reiser obtained all test data and autopilot schematics from Douglas and told me and [redacted] to complete a full stability and control analysis as soon as possible. (b)(3) I told Frank Briglia that the analysis showed no stability margin at all and that, in all probability, the vehicle would have crashed in the last test even if the accelerometer had been properly locked out during launch. This analysis was soon confirmed by Douglas, saying they overlooked the necessity of giving the latest autopilot parameters to their control system analyst.

A running battle soon developed with Dave Christ and Don Reiser putting great pressure on Frank to take a firmer hand with Douglas. Eventually, Frank elevated himself to unsupervised director of the project. I lost contact at this point, but I was not surprised some years later when Aquiline was "mothballed" with a price tag of [redacted] (b)(3)

Project Axillary

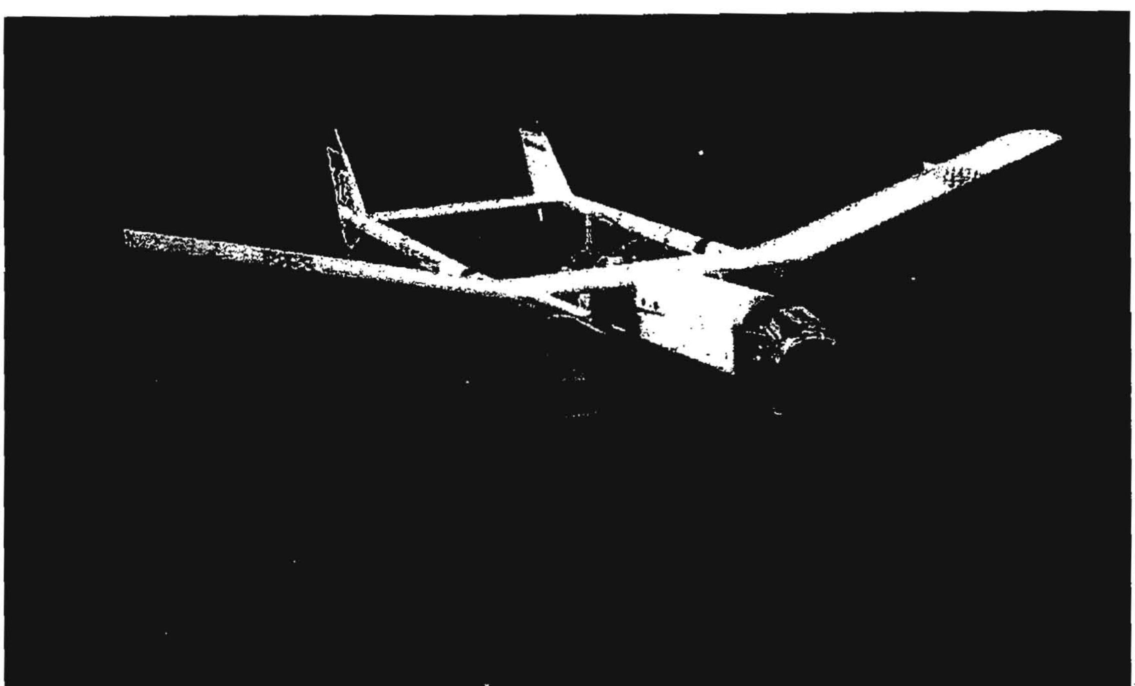
Around 1970, Don Reiser suggested some research in small lightweight autopilots. I joined the local RC club and was soon building model aircraft in my basement. I found a good RC pilot and model builder, [redacted] (b)(3) and we put together an aircraft from several model kits that looked something like a Cessna Sky Master, or P-38, with twin booms and a pusher prop. The pod-shaped fuselage opened like a clam shell for installing TV or photographic equipment in the nose; the engine and propeller were in the rear. The twin booms were fiberglass dowels that plugged into the wings. We installed a movie camera in the noise and conducted several flight tests at the local RC flying field. I showed the vehicle to Don and suggested this would make a good test bed for developing a small autopilot.

[redacted] and I designed the autopilot with com- (b)(3)
puter simulations to estimate the control gains. Its unique feature was that it had no vertical or directional gyro, which reduced the weight and power requirements considerably. We chose Melpar to build the autopilot—for less than [redacted]—and support the flight (b)(3)
tests mainly because they knew nothing of aerodynamics and employed [redacted] (b)(3)

The autopilot controlled heading, velocity (angle of attack), and altitude. The heading sensor was a two-axis magnetometer, and the angle of attack was measured by a small arrow-shaped wind vane attached to a miniature potentiometer. Someone found a Chrysler manifold pressure sensor that worked well as an altimeter.

The autopilot weighed only 3 pounds, but the batteries, voltage converters, and down-link telemetry increased the launch weight to 20 pounds. Takeoff at this weight was dangerous, particularly in any kind of crosswind. [redacted] solved the problem by building a cartop launcher (b)(3)
out of plywood, plumbing T's, and a rolling caster that let the vehicle rotate into any crosswind for launch. The autopilot was developed and flight-tested in six months without any losses.

Aquiline



Axillary

(b)(1)
(b)(3)

[redacted]

(b)(1)
(b)(3)

[redacted]

The Cuban Scenario

In the mid-to-late-1970s, there was considerable interest in Cuba. The Soviets had held large-scale maneuvers, and everyone was scrambling for data. I spent some time with the Cuban analysts to find out just what their requirements were. [redacted] The analysts wanted a low-cost covert way of getting photography on a cloudy day.

(b)(1)
(b)(3)

[redacted]

(b)(1)
(b)(3)

[redacted]

(b)(1)
(b)(3)

[redacted]

(b)(1)
(b)(3)

[redacted] (b)(1) (b)(3)

Dkcryst

Aerovironment was a small innovative aerodynamics firm in Pasadena. Its president, Paul McCready, had won prizes for manpowered flight over a land course and for flight across the English Channel. By the early 1980s, the firm had also built the Solar Challenger and flown the channel under solar power. Phil Eckman, Director of ORD, had come from JPL in Pasadena and wanted to look into solar flight at high altitudes.

I knew that Ray Morgan at Aerovironment was the real brains behind the Solar Challenger. He was a product of Lockheed's "skunk works" and good at composite structures and electric motors. Years later he would design Sun Racer for GM and win the race across Australia for solar-powered cars.

I went to Ray with some ORD research on high-efficiency solar cells and asked him to design a solar vehicle that could fly at 70,000 feet. Ray designed a 200-foot-span vehicle that he thought would stay up many days, depending only on component reliability and solar-cell efficiency.

Phil Eckman liked the design and decided we should build a half-scale unmanned vehicle that could fly with batteries while ORD continued research on solar cells. While Ray was building the vehicle, [redacted] and I designed a stability system to dampen pitch oscillations; to save weight, the aircraft had no tail. (b)(3)

The 100-foot-span vehicle was moved [redacted] in various pieces and assembled for the flight tests. When I arrived [redacted] said, "Everything is very high tech here, how about a look at your machine?" I had not yet seen it all in one piece, and we traveled to a remote hanger on the edge of a dry lakebed. The overhead lights reflected off the clear mylar skin, and the wings sagged under the weight of eight electric motors. It looked like a transparent pterosaur with bones of fiberglass and Kevlar. Below the tailless wing was a clear plastic pod and "baby carriage" wheels with a bungy shock absorber. Sharp was dumbstruck, so I mentioned that this was a very "high tech" ultralight with latest state-of-the-art composite construction. I do not think he was impressed. (b)(1) (b)(3) (b)(1) (b)(3)

The preliminary flights were without incident, except for one hard landing that required some structural repair. The final test was planned for 3,000 feet with over an hour's flight for recording performance parameters.

I thought everything was going pretty well until I got a call from Phil Eckman saying that Deputy Director of Central Intelligence John McMahon was showing up for the final flight and that two unexplained observers from the DS&T would be arriving the next morning. To make matters worse, [redacted] told me the day before the flight that bad weather was moving in. There was a 50-percent chance the dry lakebed would turn into a sea of mud. He said we would have to move the bird to a main hanger for takeoff from a concrete runway. Ray Morgan and I decided not to move the vehicle and to risk the rain. (b)(3)

The next morning, we learned the rain had just missed the dry lakebed. The vehicle had no trouble taking off and climbed easily to 3,000 feet. The cameras took pictures and the down-link recorders monitored power, velocity, rate of climb, and other performance data. The vehicle landed perfectly, and we all retired to the base pub for drinks and cheers.

One of the S&T observers ran several studies at JPL for finding a mission scenario that would work with current solar-cell technology, but either the mission goals or the cells' efficiency were always a little short. I let a small contract to mothball the vehicle and had it stored at one of our sites in Texas. (Years later, Ray Morgan secured a contract with the Department of Energy (DoE) for research in solar-powered flight. We declassified everything in Dkcryst and turned it over to DoE. The April 1994 issue of *Popular Science* contains an excellent illustrated article on this solar-powered vehicile.)

Things That Flap to Fly

By about 1970 research had been done on a variety of animal platforms, from dolphins to cats. There were mechanical rats, little robot cars, and other projects that showed remarkable correlation with the *Mission Impossible* TV series. There was even a small flying saucer that avoided obstacles by use of sonar. During the 1970s, I had three projects that flapped to fly: Ornithopter, an eight-foot-span mechanical bird that was the first to fly with full remote control; Insectorhopter, a laser-guided bug that looked just like a dragonfly; and Project Tacana, the use of homing pigeons to collect photography over selected denied areas.

Ornithopter

This project began when C. V. Noyes came in with a *Life* magazine article about a professor at Long Island University that was testing the efficiency of flapping-wing devices. We soon learned of a Percival H. Spencer, who had a flying ornithopter designed for Mattel's toy market. Flight tests showed the propulsion efficiency of these flapping mylar wings was quite poor.

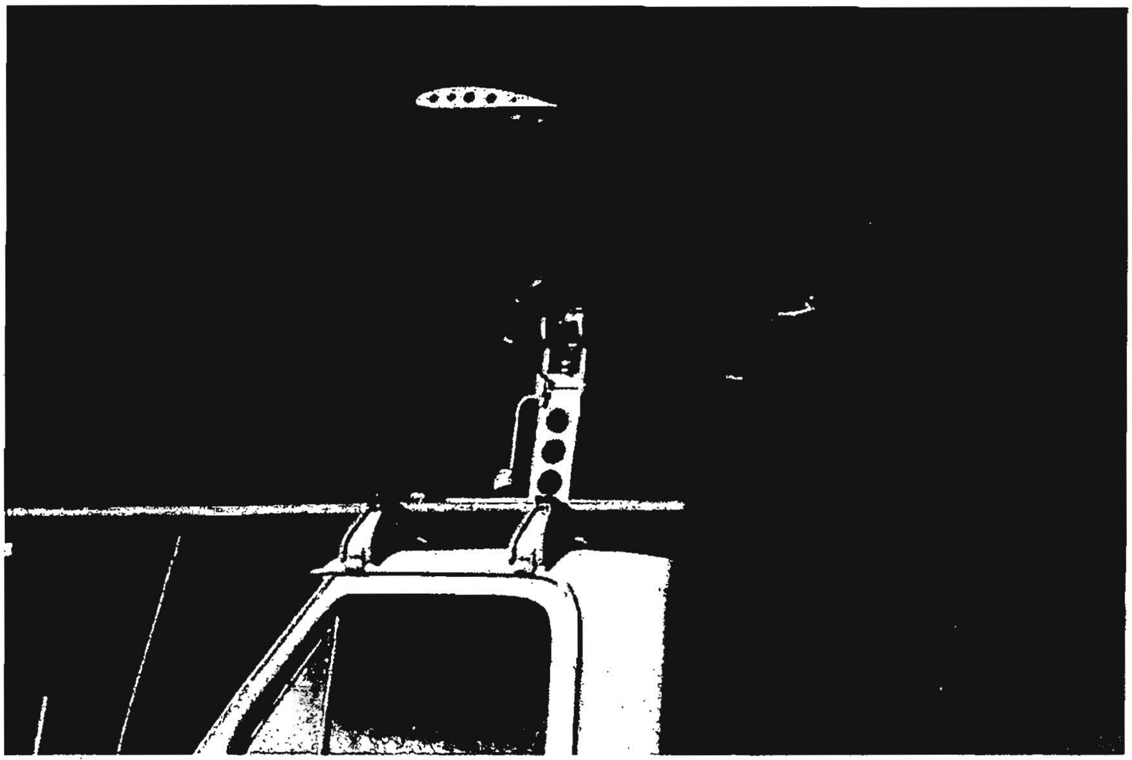
(b)(3) I next tried [redacted] We commissioned [redacted] to design an ornithopter and had Fairchild Hiller build the flight-test model. Movies of the flight looked impressive, but the only thing holding it up was a standard model engine and propeller. At this point I decided to give up on floppy mylar and fabric wings. The wings should have real airfoils and act like a large propeller, with the tip twisted up on the up stroke and down on the down stroke. My calculations showed that if the wing could be twisted properly during the flapping cycle, it should have the same thrust-to-power ratio as a helicopter.

I next went to the Advanced Technology Center (ATC) in Dallas and found an aeronautical engineer and model flyer named [redacted] It did not take [redacted] long to (b)(3)
figure out how to twist a standard "built up" wing. He disconnected the spar from each of the ribs, but left it connected to the wingtip. With a latex skin, the wing could be easily twisted by rotating the spar where it entered the fuselage.

The only problem remaining was to build a gearbox that could convert the high-speed rotary motion of an engine into the low-speed flapping and twisting motion for the wing. This turned out to be a difficult and costly problem, with more weight than planned. By the time the wind tunnel tests were complete, we had enough money for only one flight test. The vehicle was placed in a carriage on top of a pickup and the engine was started. As the pickup reached launch speed, the vehicle looked and sounded like a screaming bird straining to be released. It was difficult to control but climbed with remarkable ease. I felt the research was a success, but its use remained elusive. The scaling laws for larger vehicles, faster speeds, and useful payloads did not fit well with flapping flight and heavy mechanical parts. (The film of this flight test still exists.)

Insectothopter

Don Reiser showed me a handful of tiny glass beads. He said they were miniature retro reflectors that ATC in Dallas was working on. When developed, they would act as remote microphones by modulating the reflected beam of a laser. The problem he addressed was how to propel them to windowsills, over embassy walls, or next to a park bench. I mentioned a few ideas like BB guns and blowpipes, but Don was not



Ornithopter

impressed. He said, "I want you to build a bumblebee that can fly down the laser beam and land next to the target." The enormity of what he said left me speechless.

(b)(3) Rather than argue, I went to see [redacted] at ATC and spent most of the morning analyzing the flight requirements of a bumblebee. The wing loading was much too high and the stability, guidance, and control seemed impossible. [redacted] decided to call in an elderly scientist from the darker regions of his lab whose hobby was watchmaking. (b)(3)

The scientist listened patiently to the problem we posed and our analysis of the bumblebee. We waited for his response, hoping to collect more ammunition to counter Don's request. Finally, he spoke: "The dragonfly has a much lower wing loading and is quite stable in glide." (b)(3) [redacted] and I looked at each other and said with one voice: "How do you know?" He said, "I have a small collection at home. I'll bring one in after lunch."

That afternoon we used a magnifying glass to observe this petrified beast mounted on the end of a stickpin. The scientist pointed out, with some pride, the waffled texture of the wings. "This serves the same purpose as pits on a golf ball; they trip the boundary layer and prevent laminar separation at the low Reynolds number." Sid and I pressed the point on glide stability. The old fellow plucked the insect from its perch and tossed it into the air. It made about two circuits and landed nicely on the desk.

We then discussed the problem of propulsion. The scientist felt he could build a miniature fluidic oscillator to propel the wings up and down at the proper rate. A small amount of liquid propellant and oxidizer could be mixed together to produce a large quantity of gas to drive the oscillator; the excess gas could be vented out the rear for forward thrust. By varying the power in the laser, a bimetalic strip in the insect's tail would cause it to steer right or left. Turning off the laser would cause the cooled strip to block the exhaust port so the vehicle would land on command. I did not know whether to cheer or to cry—the concept of an insectothopter did seem feasible.

When the mechanical dragonfly was constructed, the elderly scientist built a miniature wind tunnel using his skills as a watchmaker. The mechanical and petrified bugs were identical, and I had both mounted in a display box. In the corner was a valve controlling a can of freon. With the valve on, the mechanical version flapped and sounded like the real thing. Though the flight tests were impressive, control in any kind of crosswind was too difficult. (I still have film of the flight test.)

Tacana

After Dave Christ retired, Don Reiser moved up to the front office. He was deputy director of ORD and later acting director. Don told me of a test he had observed

(b)(1) (b)(3) [redacted]

(b)(1) (b)(3) The [redacted] tests were to demonstrate the ability of different kinds of birds to fly to specific targets, take pictures with small cameras, or emplace small devices, and return. According to Don, however, nothing worked. The cameras did not take pictures, and the homing pigeons flew in the wrong direction. I was starting to get that queasy feeling. Every time Don told me a hardluck story, I knew he was getting ready to ask me to do something.

(b)(1) (b)(3) Don posed the problem [redacted] m take pictures on their way home to the consulate. The first thing I noticed was that the camera was far too heavy. The bird weighed about 450 grams, and the camera weighed at least 90. The camera contractor was [redacted] who used to be chief scientist for McDonnell in St. Louis and now lived on a sheep ranch with his 10 kids. (b)(3)

[redacted] and I got together in his workshop to discuss reducing the camera weight. He designed the film takeup spool to just fit over the small electric motor, and put the watch batteries in the hole of the supply spool. There was enough 8mm film for about 200 pictures that clicked off at one per second. The aerodynamic drag was reduced by rounding off the corners to fit the curvature of the film spools. The final camera weight was just over 40 grams. (b)(3)

I then looked through the Agency personnel records to find an employee who knew something about homing pigeons. I came up with [redacted] who learned the sport of racing homing pigeons as a boy, and I had him transferred to ORD to help in understanding the limits and abilities of these strange birds. I learned that modern homing pigeons could fly more than 600 miles in a day. This was equal to a human running a marathon, however, and few had such abilities. (b)(3)

Since the mid-1800s, when the first carrier pigeon labored across the English Channel to bring news from the Continent, there has been a tremendous increase in pigeon performance. This has been accomplished by the evolution of empirical methods for culling and by the selection of pairs for the breeding of new generations. [redacted] knew these methods, as did most who were successful at the sport of racing. [redacted] got a pair of birds from a friend in Oregon and put them in an empty air-conditioner shell mounted in an upper window of his home. The birds could see out through the grill, and, after they were on eggs, he cut a hole in the top and installed a ramp so they could climb in and out. (b)(3)

After a few weeks, the magnetic and solar map of "home" was firmly imprinted in the birds, and we took them short distances in a covered crate and then released them to fly home—first a block, then a quarter of a mile, and then a mile. A dummy camera was used to familiarize the birds with the harness and extra weight.

The birds were finally taken to the other side of Andrews Air Force Base, 18 miles from their home in Falls Church. A plastic tab, insulating the batteries, was pulled at release to start the camera. The camera took one picture per second for over three minutes. We took these pictures to NPIC, and they were impressed with the photographic detail of military aircraft on the runways at Andrews. NPIC agreed to help with high-resolution film and mensuration.

The problem now was to gather statistics for photographing a particular item in a target area. This required several cameras and many birds. My attic in Falls Church was made into a loft, resembling the proposed [redacted] More than a dozen pairs of birds were acquired from Oregon, Alaska, and Virginia. The air-conditioner shell was fixed to the end of the attic. While these birds were being trained to learn their new home [redacted] was improving the camera design and providing a total of six devices for the coming tests.

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(b)(3)

The chosen target was a small park within the Washington Navy Yard. Among other things, it contained a cannon, a one-man sub, and a Navy drone. Launch points on and east of the 11th Street Bridge were chosen in order to cause the birds to fly over the target on their way west to Falls Church, 15 miles away. NPIC supplied color film and developed the target pictures.

The question of a clandestine launch was addressed at one point during the tests. [redacted] had an old Volkswagen noted for the number of holes in its floorboards. We took several birds to a parking lot east of the 11th Street Bridge, which was congested with rush-hour traffic. The birds were put through the holes in John's car onto the ground. They walked out past the traffic and passersby and took off, disappearing over the Navy Yard. We tried to observe if anyone had noticed the birds or their small cameras. To our knowledge, no one did.

(b)(3)

Once the habits of the birds were understood, the number of launches required for a reasonable probability of photographing the target was not large. The Office of Technical Services (OTS) was involved during the early part of the project, when [redacted] was having difficulty training the birds. By the time the final research was published, Don Reiser had been transferred to another office, and OTS was no longer interested. I still have one of these tiny cameras in my desk drawer, complete with small squares of Velcro that held it to the bird.

(b)(3)

Postscript

Some years ago, the Smithsonian contracted with Aerovironment to build a small "pterosaur." They wanted it to flap its wings and fly around the desert so the Smithsonian could take three-dimensional I-Max movies for showings at the Air and Space Museum. As a prelude to the first showing, the mechanical bird was scheduled to flap around the Mall, impressing all with the beauty of the prehistoric beast.

Aerovironment called a symposium of leading aerodynamicists from around the country. Phil Eckman managed to get us on the agenda with these august scientists. When we arrived, we heard various arguments about how, why, and if birds could really fly. I showed films of the Ornithopter and Insectohopter flight tests; most were impressed, and a few were disappointed it had already been done. After the film, the director of the Air and Space Museum told me he wanted the dragonfly for the Smithsonian. Phil agreed, and I was pleased the public could finally see some of the research ORD had done. I loaned Aerovironment the flight film and the wind tunnel version of the ornithopter flapping mechanism.

The desert flight tests provided all the film the Smithsonian needed, but the flight around the Mall ended when the flapping pterosaur came apart in midair. I called ARPA to retrieve the dragonfly and display box for the Smithsonian, but I was told they had been lost. In any case, I got a free ticket to the first showing of the I-Max movie.

This article is ~~SECRET~~.