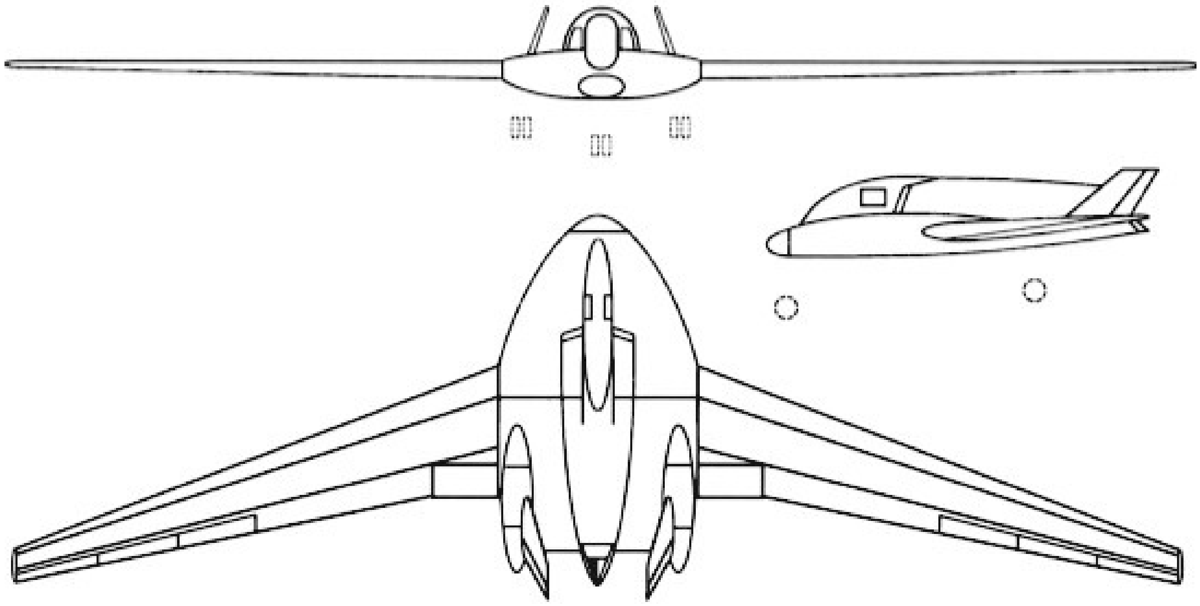
No. 346 **APRIL 2015**

T.W.I.T.T. NEWSLETTER



Unmanned proposal of the M-67 project designated M-67BVS-LK. Long endurance, low observable for surveillance. Source: http://andriuha077.narod.ru/aero/m67-variant-kreiser-lkm.html

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

The number after your name indicates the ending year and month of your current subscription, i.e., **1504** means this is your last issue unless renewed.

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis.

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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive (#1720), east side of Gillespie or Skid Row for those flying in).

TABLE OF CONTENTS

PRESIDENT'S CORNER

This issue starts the tumbling phenomenon article I mentioned last month. I have tried to make it as readable as possible from its original form since there were too many formulas and figures to effectively convert it into a text file and produce a new type of original document.

I have also revised the page order so you can see the figures mentioned in page 2 on the following page rather than having to wait until next month for those pages.

Next month will provide the last of the figures and illustrations along with the listing of reference materials.

I hope everyone enjoys this material since it probably has been lost over the years and not readily available through an Internet search. I haven't tried looking for things like this, but if any of you have been researching various topics and come across these older items relating to tailless aircraft, I would be interested in having the links.

For those of you on the west coast I will start promoting the Experimental Soaring Association's Western Workshop coming up during the Labor Day weekend at Mountain Valley Airport in Tehachapi, CA. Saturday and Sunday will be full of great presentations on a wide variety of aviation topics. Plus there is a commercial operator providing aero tows so you can bring your ship with you and do some late summer flying.

Andy

PRELIMINARY RESULTS OF EXP'L AND ANALYTICAL INVESTIGATIONS ON THE TUMBLING PHENOMENON FOR AN ADVANCED CONFIGURATION

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Abstract

A sustained autorotative pitching motion usually called "tumbling" has been observed during dynamic model tests of the X-29A configuration. The X-29 is an advanced design incorporating forward-swept wings and canards in a highly relaxed static stability condition. Beginning with a historical review of the tumbling phenomenon, this paper discusses the current experimental results of dynamic model tumbling tests of the X-29 and the initial efforts to establish an aerodynamic and mathematical model for analysis.

Symbols

$\bar{c}$	mean aerodynamic chord, ft
C_m	pitching-moment coefficient
C_{m_q}	$\frac{\partial C_m}{\partial \frac{q\bar{c}}{2V}}$
C_{m_s}	static pitching-moment coefficient
$C_{m_{\dot{\alpha}}}$	$\frac{\partial C_m}{\partial \frac{\dot{\alpha}\bar{c}}{2V}}$
G_x	longitudinal acceleration, g
G_z	normal acceleration, g
I_y	pitch inertia, slug-ft^2
q	pitch rate, deg/sec
$\dot{q}$	pitch acceleration, deg/sec^2
q_{ss}	steady state pitch rate, deg/sec
$\bar{q}$	dynamic pressure, psf
S	reference area, ft^2
t	time, sec
V	freestream velocity, fps
α	angle of attack, deg
δ_c	canard deflection, deg
δ_f	flap deflection, deg
δ_s	strake deflection, deg
θ	pitch attitude, deg

Introduction

Air combat maneuvering requirements have forced aggressive exploitation of high angle of attack flight conditions. Today's first line fighters employ the full spectrum of high angle of attack design features developed through a decade of research: forebody aerodynamics, strakes, vortex flows, and control laws which not only prevent departures and spins, but enhance maneuvering at angles of attack well beyond stall[1]. The concurrent improvement of air to air missile capabilities has not, however, decreased the airplane's requirements for maneuverability. In fact, "point and shoot" missiles seem to drive designs toward ever increasing maximum pitch rates.

The high-alpha design task up to this time has been primarily in the lateral-directional axes, to provide control and prevention of spins, roll divergence, wing rock, and nose slice departures. Alpha limiting, where required, has typically been mandated by the lateral-directional characteristics of the airplane, but the increasing levels of relaxed static stability in use today have amplified the potential occurrence and severity of the deep stall phenomenon.

Present design trends emphasizing relaxed static stability, including features such as forward wing sweep, canard controls, and tailless configurations, accentuate pitch control requirements. The combination of the desire for very high pitch agility and modern design trends may well introduce a severe out-of-control problem in the pitch axis: tumbling. Tumbling, defined as a sustained autorotative pitching motion, has been recently observed during dynamic model tests of one advanced design, the X-29A forward swept wing research airplane. Figure 1 is a 3 view drawing of the X-29A and Figure 2 is a photograph of the model.

This appearance of the tumbling phenomenon for the X-29A has led to the implementation of a research effort to establish the aerodynamic and inertial factors involved in tumbling and to provide design guidelines to prevent an in-flight occurrence. This paper presents the preliminary results of the experimental and analytical investigations.

Historical Background

Dynamic model free-tumbling tests were performed in the Langley vertical spin tunnel during World War II and continued through the early 1950's. Reference 2 mentions the phenomenon of tumbling reported in 1942 for "a conventional fighter airplane" (no further identification) and cites a fatal crash of a tailless airplane which might have been tumble related. Spin tunnel investigations established the existence of the phenomenon in model tests and tumble tests were often included in the normal spin tunnel program, especially for tailless configurations.

Reference 2 is a summary of the tumbling results for 14 model configurations, including considerations of emergency recovery parachutes, accelerations on the pilot, and pilot escape. These 14 designs represented a wide diversity of aerodynamic approaches including conventional fighters, a tail-first configuration (figure 3), an extremely close-coupled model[3] (figure 4), a forward-swept wing[4] (figure 5), flying wings[5] (figure 6), a "flying saucer"[6] (figure 7) (the term "flying pancake" was used at the time), a tailless type (figure 8), and a simple delta wing. From the observations of these free-tumbling tests, the authors drew a number of conclusions, quoted here directly.

1. Conventional airplanes will not tumble, whereas tailless and tail-first airplanes may tumble.

2. Increasing the static longitudinal stability tends towards the prevention of tumbling.

3. Tailless airplanes having low aspect ratio and a large pitching inertia parameter (I_y/mb^2) are less likely to tumble than those having high aspect ratio and a small pitching inertia parameter.

4. Ailerons and rudder have little or no effect on tumbling.

5. Movement of the elevators to oppose the tumbling rotation will generally be effective in producing recovery from a tumble when the static longitudinal stability is marginal.

6. Two parachutes, one attached to each wing tip, will generally be effective in producing recovery from a tumble.

7. Accelerations in a tumble may be exceptionally dangerous.

The first two conclusions suggest the reason for the rapid decline in tumbling interest after this period. Most new designs were conventional and statically stable. Except for the Northrop X-4 "semi-tailless" research airplane[7], and some radical VTOL entries, the aft-mounted horizontal stabilizer was nearly universal. There were delta wings[18], of course, but conclusion number three indicates little likelihood of tumbling for these designs. Brief reappearances of tumbling tests occurred in 1957, for the Ryan X-13 VTOL[8] and then again in 1964 for a radio-controlled parawing[9].

The majority of these investigations consisted of free-tumbling tests in the Langley vertical spin tunnel since the dynamically-scaled[10] models constructed for spin testing are appropriate for tumbling studies. The results are essentially a yes/no for each test configuration, so generalizations can only slowly evolve from numerous tests. Analytical efforts toward understanding the basic tumbling phenomenon have been quite limited.[11] One of the earliest attempts, by A. M. O. Smith[11] in 1950 was prompted by tumbling concerns for an ejection capsule for the D-558. Smith analyzed several aspects of the motion including hysteresis effects on lift coefficient, Reynolds number effects on drag coefficient, the "anemometer effect", a coupling effect, a shed vortex field effect, and a Flettner rotor effect.

Only for the case of the parawing[9] was a set of static aerodynamic data obtained through 360° angle of attack. Measurement of dynamic derivatives and the computation of tumble trajectories was not attempted. Certain "pro-tumbling" features identified in this early research have reappeared in the X-29A configuration and these features are seen in proposed future high performance aircraft: tail-first (X-29A canard) and tailless designs, relaxed static stability for agility; low pitch inertia and high aspect ratio of tailless aircraft e.g. flying wings. The NASA Langley Research Center has instituted a tumbling research effort to address this phenomenon for contemporary designs.

Experimental Investigation

The experimental investigation was conducted in the Langley 20-foot vertical spin tunnel. A description of this facility is given in reference 12. Tests were performed using a 1/25-scale model of the X-29A dynamically scaled in weight and inertia to an equivalent full-scale altitude of 25,000 feet.

Free-tumbling tests

In free-tumbling tests, a dynamically scaled model is launched into the vertically rising airstream from any desired attitude, with or without an initial pitch rate. The ensuing motions are recorded on high-speed color movie film. Initial tests for the X-29A were conducted in the high alpha configuration: wing flaps full down, strake flaps 30° down and canard 60° trailing-edge up, i.e., the flight control system commanding maximum nose down moments. When released from a nose-high attitude ($\alpha = 180°$) in this configuration, the model underwent an irregular, but clearly autorotative pitching motion in the nose-down sense. There was a horizontal translational component to the trajectory and the model impacted the tunnel safety net after a few tumble cycles.

The observed motion was complex with cyclic variations in linear as well as angular rates. After release, the model would accelerate in pitch and forward velocity, passing rapidly through 0° angle of attack. As the motion progressed beyond -90° angle of attack, the pitch rate slowed very noticeably until the nose-highpoint (α - -180°) was reached, when the model would once again accelerate into the next cycle. There was a marked sensitivity in the lateral-directional axes, and any asymmetry in control settings caused the model to rotate out of the pitch plane into assorted wild gyrations. Attempts to induce a nose-up rotation were unsuccessful for this configuration.

Large-deflection nose-mounted canard surfaces provide powerful pitch control for the X-29A. A series of tests were conducted over the range of canard deflection, but there was no significant change in the behavior of the model. The model tumble motion, converted to full-scale values for the airplane, correspond to pitch rates varying from 20° per second to over 200° per second (averaging 120° per second) at a sink rate on the order of 250 feet per second.

Free-to-pitch tests

The complexity of the model motions and the extremely limited run time for each free-tumbling

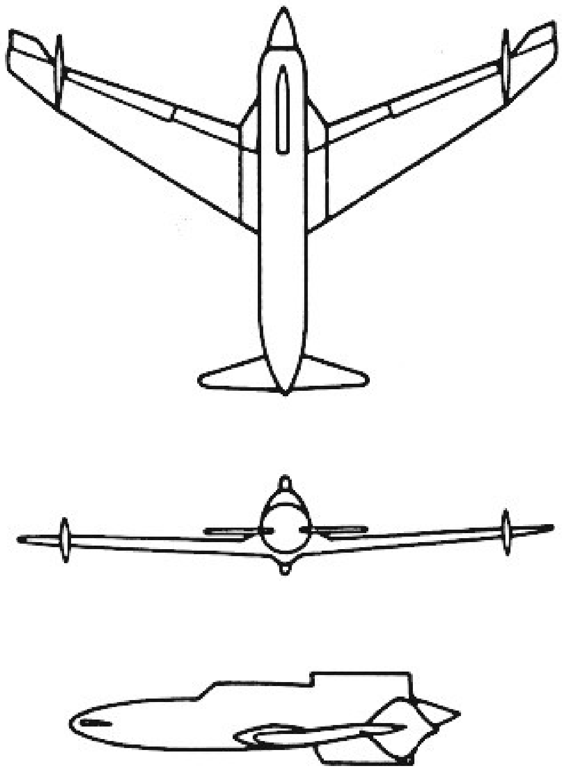


Figure 3.- Three-view drawing of the XP-55.

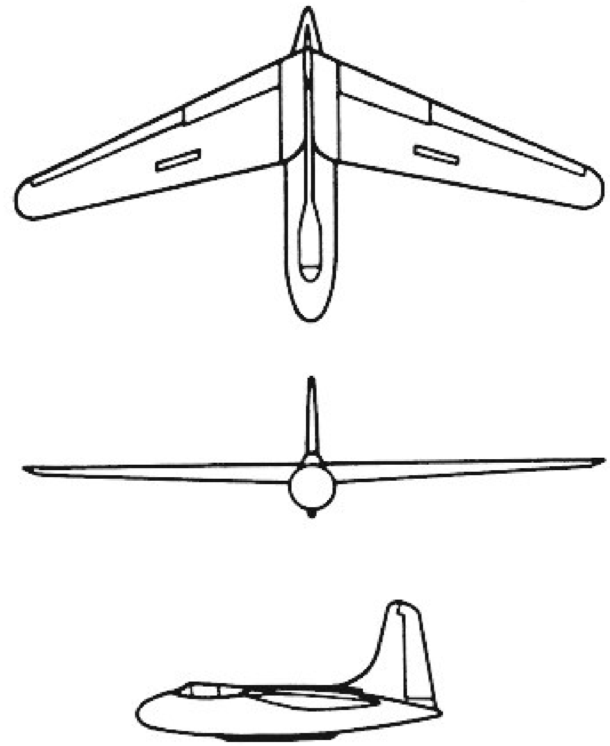


Figure 5.- Three-view drawing of the Cornelius Glider.

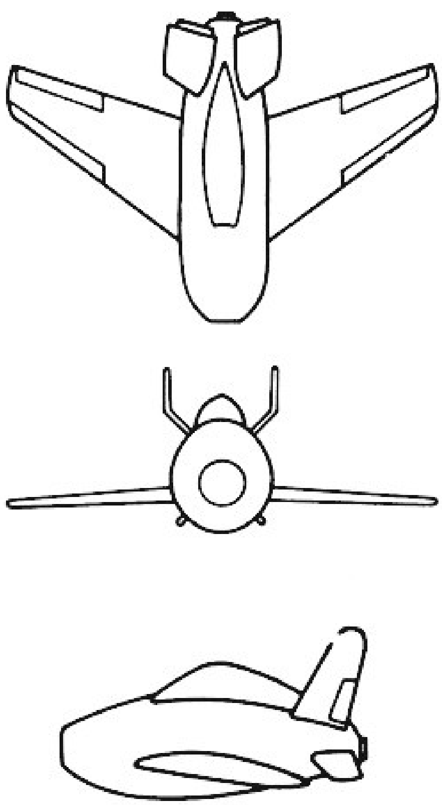
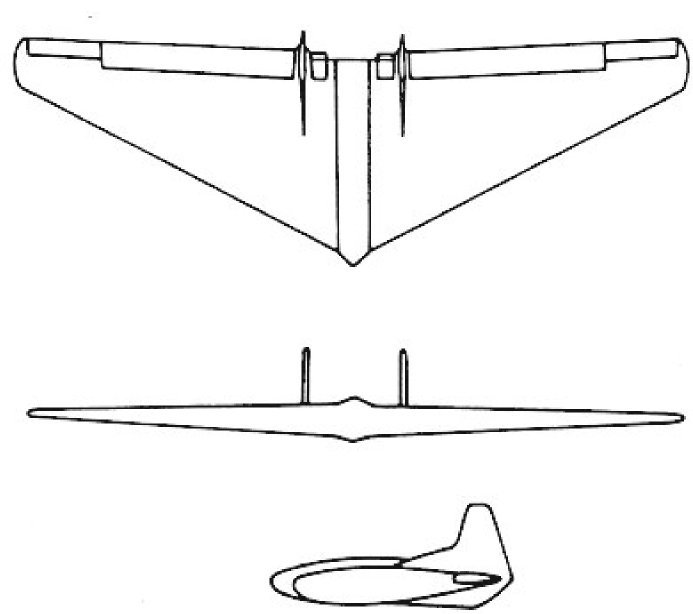
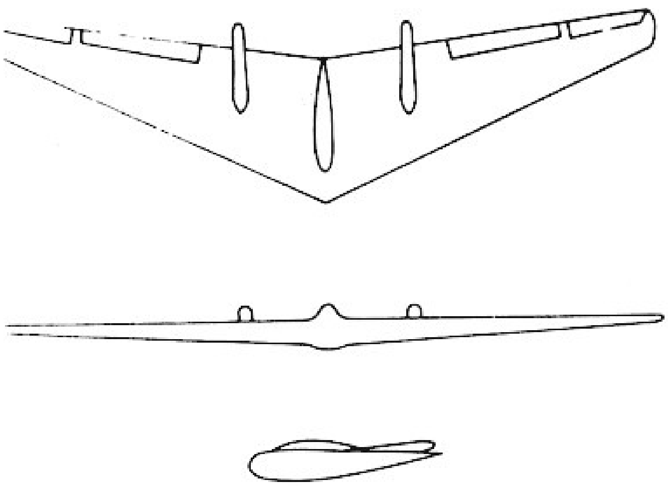


Figure 4.- Three-view drawing of the XF-85.

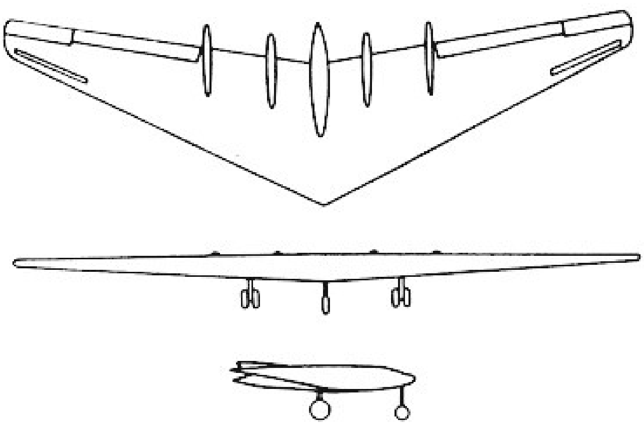


(a) XP-79

Figure 6.- Three view drawings of flying wings.



(b) N-9M



(c) XB-35

Figure 6.- Concluded.

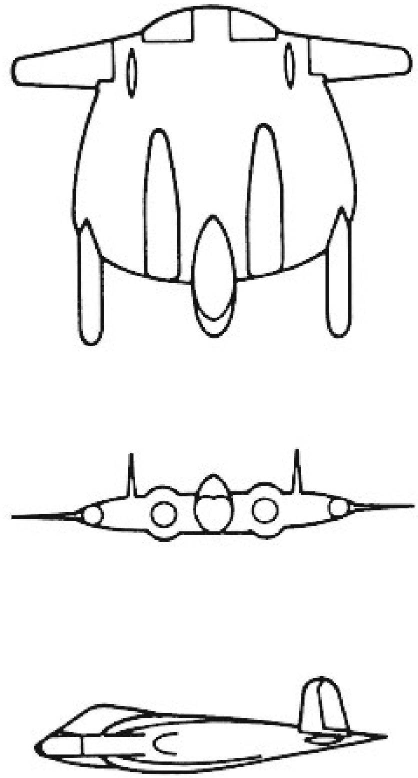


Figure 7.- Three-view drawing of the XF5U-1.

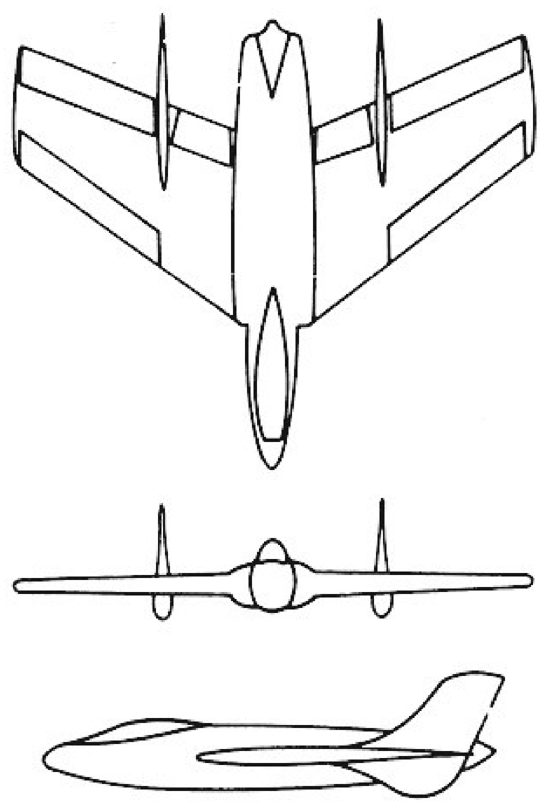


Figure 8.- Three-view draw'ng of the XF7U-1.

made analysis very difficult. In an effort simplify the motion and expand test duration, the free-to-pitch test was implemented, essentially reducing the problem to a single degree of freedom. In this technique the same dynamically scaled model was mounted at its center of gravity on bearings so that it was free to rotate in pitch only (figure 9). An attempt was made to minimize the friction in the system.

As the tunnel velocity was increased from zero, the model rotated to a trim attitude, often oscillating about this position. Autorotation never developed from these oscillations even at tunnel speeds well beyond the free-tumbling sink rates. Imparting an initial rotation to the model in the proper direction would produce an autorotation which persisted indefinitely. This autorotation was obtained for speeds equivalent to 150 to 300 feet per second. The effect of control surface position on this motion was studied by setting the controls to the maximum positive, negative, and neutral positions. The canard had little discernible effect on the motion while the wing flaps showed only a small effect. The strake flaps, on the other hand, demonstrated a very strong effect on the motion. With the strake flaps deflected 30° down, only nose-down autorotation could be induced. Attempts to force a nose-up rotation either damped out or reversed to the nose-down motion. Reversing the strake flaps to 30° up (take-off position) permitted a nose up autorotation. At the neutral position, the strake flaps enabled a somewhat weaker autorotation in either direction. Wing flap deflection tended to strengthen or weaken the strake flap influence, but could not change the predominant strake flap effect.

These results suggested the possible effectiveness of the strake flaps as a tumble control device. Tests were conducted in which an autorotation was established for a fixed strake flap setting. The strake flaps were then reversed to the full opposite setting and it was found that the motion damped out in three to four tumble cycles. Addition of wing flap motion in the appropriate direction further improved the damping and halted the motion in two to two and a half tumble cycles.

Free-Tumbling and Free-to-Pitch Tests of A Conventional Configuration

As a check on the experimental techniques, free-tumbling and free-to-pitch tests were conducted on a dynamically-scaled model of a current fighter airplane with a conventional aft-tail geometry, and a conventional level of static pitch stability. As expected, it was not possible to induce a tumbling motion with either technique for this model.

Analytical Investigation

An important objective of the current effort was to develop a valid mathematical model of tumbling so that the phenomenon can ultimately be studied in piloted simulation. As a first step toward this goal and to help establish understanding of the fundamentals involved, an analytical model of the single-degree-of-freedom free-to-pitch situation was developed. For this case, the governing equation of motion is given by:

$$I_y\dot{q} = \bar{q}S\bar{c}\,C_{m_{TOTAL}} \qquad (1)$$

For simplicity, the total pitching-moment coefficient is modeled as comprising a static term and a damping term. It is recognized that this conventional aerodynamic model may not be entirely valid for the tumbling condition. With this model, equation (1) becomes:

$$I_y\dot{q} = \bar{q}S\bar{c}\left(C_{m_s} + C_{m_q}\frac{q\bar{c}}{2V}\right) \qquad (2)$$

Some insight into the roles played by the static and dynamic terms is gained by analyzing equation (2) in the spatial domain instead of the time domain. Following the development of Smith (reference 11), let $q = \frac{d\Theta}{dt}$ then

$$\dot{q} = \frac{dq}{dt} = \frac{dq}{d\Theta}\frac{d\Theta}{dt} = q\frac{dq}{d\Theta} \qquad (3)$$

Substituting (3) into (2) yields:

$$I_y q\,dq = \bar{q}S\bar{c}\left(C_{m_s} + C_{m_q}\frac{q\bar{c}}{2V}\right)d\Theta \qquad (4)$$

Integrating equation (4) from an initial to a final pitch attitude gives:

$$\frac{1}{2}I_y\left(q_f^2 - q_i^2\right) = \bar{q}S\bar{c}\int_{\Theta_i}^{\Theta_f} C_{m_s}\,d\Theta + \frac{\bar{q}S\bar{c}^2}{2V}\int_{\Theta_i}^{\Theta_f} C_{m_q}\,q\,d\Theta \qquad (5)$$

where q_i and q_f are the pitch rates occurring at Θ_i and Θ_f respectively. It is clear that equation (5) is simply an energy balance for a rotating rigid body where the left hand side is the total change in kinetic energy and the right hand side is the external work done to the body. The first integral states that the work done by the static aerodynamic term is directly proportional to the area contained under the C_{m_s} versus Θ (or equivalently α) curve. Thus, if static data is available over the complete tumbling cycle of 0 to 360°, a determination of the area under the C_{m_s} versus α curve will indicate the preferred direction of the tumbling mode if it exists. A significant negative value (mostly negative C_m) indicates a nose-down tumbling tendency whereas a positive value suggests a nose-up preference.

For a steady-state tumbling condition, the net energy change over one cycle is zero, thus equation (5) becomes:

$$\int_{\Theta_o}^{\Theta_o + 2\pi} C_{m_s}\,d\Theta + \frac{\bar{c}}{2V}\int_{\Theta_o}^{\Theta_o + 2\pi} C_{m_q}\,q\,d\Theta = 0 \qquad (6)$$

Thus, for a steady-state autorotative motion, the work done over a cycle by the static aerodynamics must be offset by the dynamic or damping contribution. Equation (6) can be used to obtain a rough estimate of the average autorotating pitch rate by assuming that q is invariant with Θ :

AVAILABLE PLANS & REFERENCE MATERIAL

Tailless Aircraft Bibliography

My book containing several thousand annotated entries and appendices listing well over three hundred tailless designers/creators and their aircraft is no longer in print. I expect *eventually* to make available on disc a fairly comprehensive annotated and perhaps illustrated listing of pre-21st century tailless and related-interest aircraft documents in PDF format. Meanwhile, I will continue to provide information from my files to serious researchers. I'm sorry for the continuing delay, but life happens.

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Books by Bruce Carmichael:
Personal Aircraft Drag Reduction: $30 pp + $17 postage outside USA: Low drag R&D history, laminar aircraft design, 300 mph on 100 hp.
Ultralight & Light Self Launching Sailplanes: $20 pp: 23 ultralights, 16 lights, 18 sustainer engines, 56 self launch engines, history, safety, prop drag reduction, performance.
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VIDEOS AND AUDIO TAPES

(ed. – These videos are also now available on DVD, at the buyer's choice.)

VHS tape containing First Flights "Flying Wings," Discovery Channel's The Wing Will Fly, and ME-163, SWIFT flight footage, Paragliding, and other miscellaneous items (approximately 3½+ hours of material).
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

VHS tape of Al Bowers' September 19, 1998 presentation on "The Horten H X Series: Ultra Light Flying Wing Sailplanes." The package includes Al's 20 pages of slides so you won't have to squint at the TV screen trying to read what he is explaining. This was an excellent presentation covering Horten history and an analysis of bell and elliptical lift distributions.
Cost: $10.00 postage paid
Add: $ 2.00 for foreign postage

VHS tape of July 15, 2000 presentation by Stefanie Brochocki on the design history of the BKB-1 (Brochocki,Kasper,Bodek) as related by her father Stefan. The second part of this program was conducted by Henry Jex on the design and flights of the radio controlled Quetzalcoatlus northropi (pterodactyl) used in the Smithsonian IMAX film. This was an Aerovironment project led by Dr. Paul MacCready.
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

An Overview of Composite Design Properties, by Alex Kozloff, as presented at the TWITT Meeting 3/19/94. Includes pamphlet of charts and graphs on composite characteristics, and audio cassette tape of Alex's presentation explaining the material.
Cost: $5.00 postage paid
Add: $1.50 for foreign postage

VHS of Paul MacCready's presentation on March 21,1998, covering his experiences with flying wings and how flying wings occur in nature. Tape includes Aerovironment's "Doing More With Much Less", and the presentations by Rudy Opitz, Dez George-Falvy and Jim Marske at the 1997 Flying Wing Symposiums at Harris Hill, plus some other miscellaneous "stuff".
Cost: $8.00 postage paid in US
Add: $2.00 for foreign postage

VHS of Robert Hoey's presentation on November 20, 1999, covering his group's experimentation with radio controlled bird models being used to explore the control and performance parameters of birds. Tape comes with a complete set of the overhead slides used in the presentation.
Cost : $10.00 postage paid in US
$15.00 foreign orders

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BLUEPRINTS – Available for the Mitchell Wing Model U-2 Superwing Experimental motor glider and the B-10 Ultralight motor glider. These two aircraft were designed by Don Mitchell and are considered by many to be the finest flying wing airplanes available. The complete drawings, which include instructions, constructions photos and a flight manual cost $250 US delivery, $280 foreign delivery, postage paid.

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