down is shown to be delayed substantially compared to the sharp-edged wing.

Concluding Remarks

It has been shown that for the model tested in this study, Reynolds number effects are only manifested when the rate of progression of the location of leading-edge crossflow separation has slowed, which typically occurs when the separation region is close to the wing/fuselage junction. Vortex breakdown was not observed while leading-edge flow separation was progressing rapidly from the wing trailing edge to the apex. The blunt leading edge was seen to significantly delay vortex breakdown compared to a comparative sharp-edged wing.

Acknowledgment

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Ring Wing for a Compressed Missile

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Introduction

To enhance weapon/aircraft system survivability and mission success, future aircraft require advanced air-to-ground and air-to-air weapons that minimally contribute to the drag and observable characteristics of the integrated weapon system. Evaluation of potential ring wing missile applications have focused on providing a technology base from which effective low installed drag and low observable weapon/aircraft integration designs and techniques can evolve for current and future aircraft. Compared to conventional planar wings, a ring wing having equal planform area generates higher lift and greater aerodynamic efficiency (lift-to-drag ratio). By providing a physical barrier at its wingtips, spillage of high-pressure air from the lower to the upper surface of the ring wing is constrained. In this manner, typical wingtip losses are avoided. Consequently, a ring wing missile can achieve improved free-flight performance including extended range and cross range as well as provide greater maneuverability.

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Extendable Ring Wing Concept

A unique design of an extendable ring wing provides configuration flexibility while in flight that is tailored to its mission.[1] During its compressed carriage on an aircraft, the wing is wrapped around the missile's body and subsequently unfurls during the missile's free flight (Fig. 1).

Extendable wraparound tail surfaces can similarly be used. In its compact version, the missile is bullet-like in shape with minimal size and volume. A compressed ring wing missile can be carried externally by an aircraft with reduced installed drag and lowered radar reflectivity.[2] Also, many more missiles can be carried within a given-sized bay of an aircraft. In addition, a compressed ring wing missile is conducive to rearward tube-launching techniques from underwing conformal pods.

These unique features of a ring wing missile can favor a pilot with increased flexibility in his flight approach to a defended ground target. In this manner, he and his aircraft can enjoy enhanced survivability as well as enhance the success of his mission.

Compressed Weapons

By providing compressed weapon designs for internal and external carriage installations on LO aircraft, weapon loadouts, and strike force capabilities can be maximized. A ring wing flexible band design and wraparound tail surfaces have been functionally demonstrated at low speeds and are inherently suitable for achieving compressed volume compared to a conventional wing round body missile. Upon launch of the missile, ring wing extendable lifting surfaces are mechanized to deploy and provide self-extension and locking (Fig. 2).

Ring Wing Deployment Mechanisms

A flexible band ring wing was constructed from flat spring-like sheet material (aluminum; 0.040 in. thickness) and force-wrapped one circumference around the missile body's circular section in a wingtip-to-wingtip fashion. This activates resistive bending stresses within the flexible outer band structure of the ring wing, which tends to restore the panel to its planar shape. In this manner, the activation energy for ring wing deployment is supplied. To constrain the ring wing from opening inadvertently, a mechanical locking/release device is applied across adjacent wingtips. Such a device has been successfully employed during wind-tunnel demonstrations of ring wing deployment[1] on a full-scale ring wing missile test model (13.5-in. body diameter) representative of a typical air-to-ground weapon (Fig. 3). A flat metallic, holdback disk supported on a stem attached to the missile model's inner structure was used. This disk constrained the movement of the adjacent wingtip edges of the ring wing by forcing them against the missile body. Using pneumatic actuation, the disk was displaced radially away from the missile's body. This permitted the wingtips to clear the holdback disk thereby allowing the ring wing's flexible outer band to unfurl and extend. On reaching full extension, wing panel hinges were locked by square-shaped, spring-activated, axial pins. Full deployment was achieved in about 0.2 s. In low-speed airflow, similar demonstrations were made at angles of attack of +10 deg. Under these conditions,

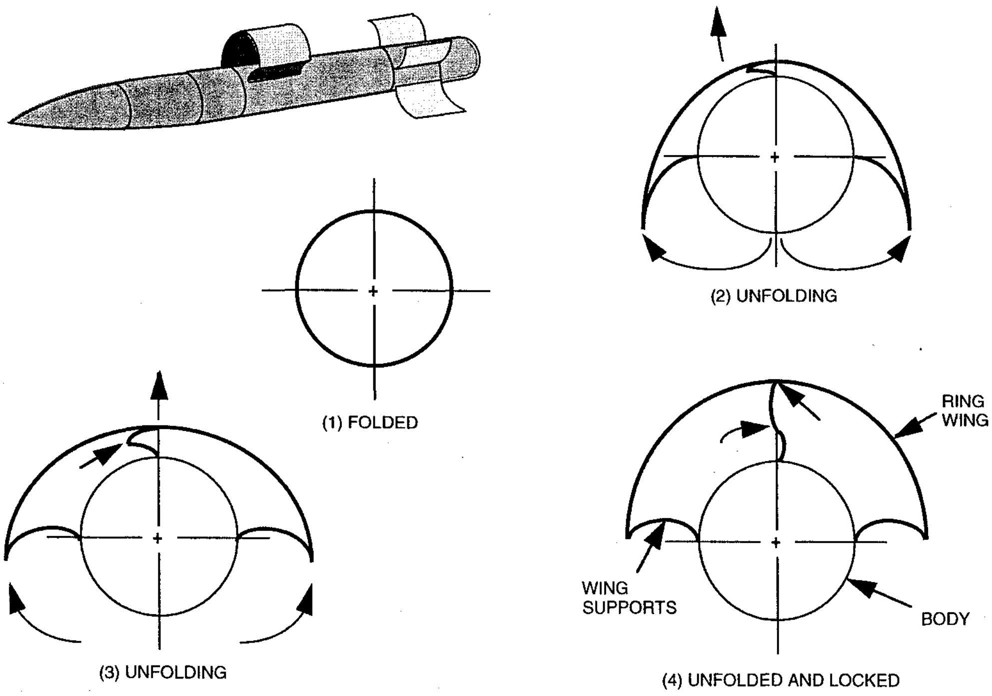

Fig. 1 Flexible band wing unfolding sequence.

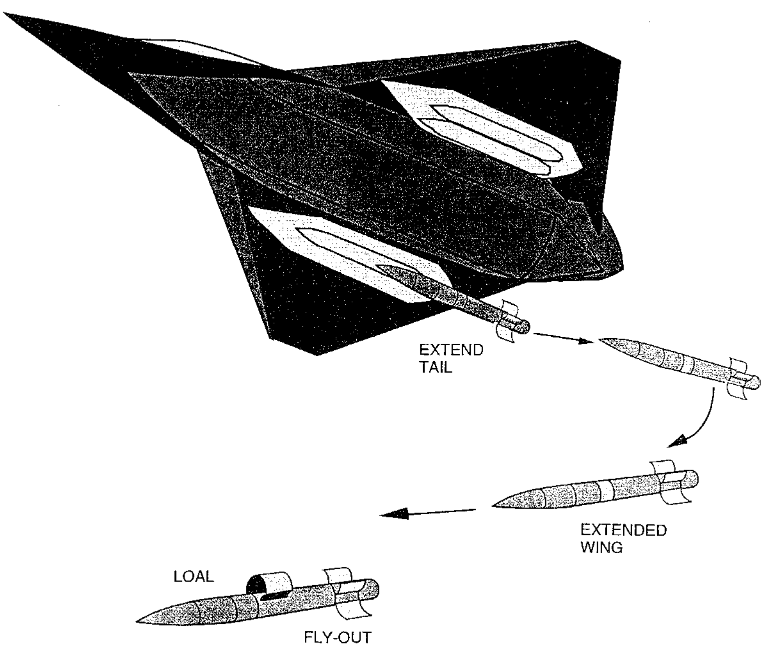

Fig. 2 Base release of tube-launched missile.

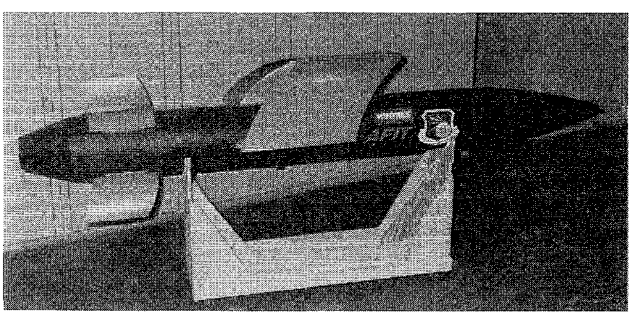

Fig. 3 Ring wing missile test model (full scale).

aerodynamic loading tends to bellow the ring wing's outer band thereby assisting its unfurling process.

Extendable Wraparound Tail Surfaces

Quarter circumference tail panels can be activated by torsional springs to rotate about their root chords away from the body and lock in a cruciform pattern. Particularly while in close proximity to the aircraft, rapid extension of the tail surfaces is needed to provide the missile with longitudinal and directional stability. Also, these erected panels are all-movable control surfaces that rotate about actuator-driven hinge lines acting through their half-chord lengths. In this manner, the missile body can be pitched and trimmed to various angles of

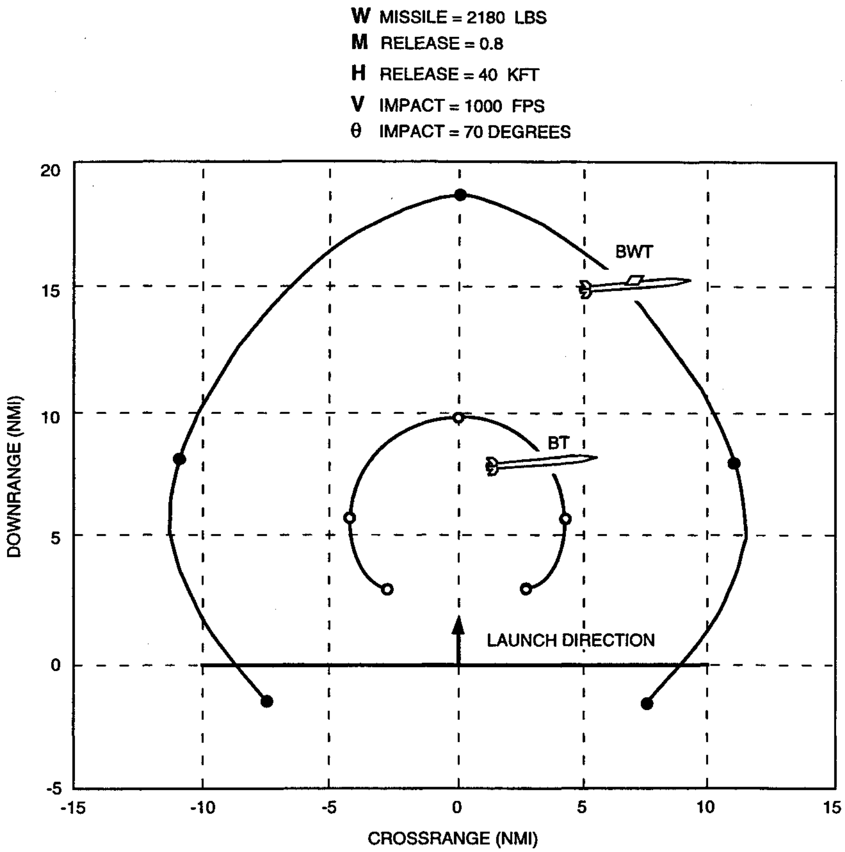

Fig. 4 Ring wing contribution to extended footprint.

attack, thereby generating lift and maneuverability to the ring wing missile.

Predicted Flight Performance of a Ring Wing Weapon

A study of improved flight performance gained by a 2000-lb class air-to-ground kinetic penetrator bomb because of the added aerodynamic lift and efficiency of a retrofittable ring wing component that can be secured on a reference store was made. Estimated flight performance data are largely based on aerodynamic wind-tunnel test results obtained on a full-scale (13.5-in.-diam) ring wing missile model (see Fig. 3) tested with its wing extended and locked [body–wing–tail configuration (BWT)] as well as wrapped around the missile body [body–tail configuration (BT)]. These test results were obtained at the Air Force Subsonic Aerodynamic Research Laboratory (SARL) facility and complemented by earlier small-scale (body diameter = 2.6-in.) aerodynamic test data performed at transonic speeds at the AEDC 4T wind tunnel where compressibility effects were measured.

For a launch condition from an aircraft at 40,000 ft altitude and Mach 0.8, estimates of ground impact footprints were made (Fig. 4). These results show significantly extended downrange and crossrange capability of the weapon because of the added aerodynamic efficiency of the ring wing weapon.

Summary of Results

Internal and external weapon loadout of advanced aircraft can be enhanced because of the compressed volume of a ring wing missile. Low-speed wind-tunnel testing of a full-scale ring wing missile design was performed. Aerodynamic test data were obtained for its compressed in-carriage configuration (wing wrapped) and its free-flight configuration (wing deployed). In a low-speed airstream (Mach 0.3) and angles of attack to +10 deg, the ring wing was successfully deployed and locked.

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