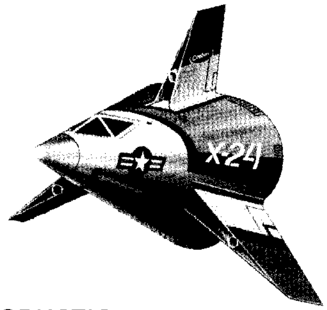
TIR-24

TECHNICAL INFORMATION REPORT

MODEL ROCKET LIFTING BODIES



INTRODUCTION

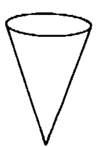
A lifting body is basically an aircraft that generates aerodynamic lift by its shape, rather than the addition of an airfoiled wing. Lifting bodies that have small wings or fins generally use these only as control surfaces. The shape of a lifting body's fuselage determines its gliding abilities.

Real lifting bodies are used by NASA and other aerospace organizations to explore the possibilities of wingless flights. Different shapes are needed at different speeds. Some, like the Northrop Corporation's HL-10, are quite sophisticated manned vehicles with movable control surfaces and a rocket engine for powered flights. Others are unmanned mock-ups dropped from airplanes to observe gliding abilities. The lifting body principle has been used to slow the descent of returning spacecraft. The heat generated by friction during re-entry is spread out over the large area and thickness of the body. If wings were used at these high speeds, they would heat up too much and become unable to withstand the tremendous stresses of re-entry.

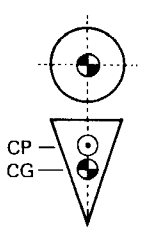
The Centuri X-24 Bug is used in this report as a model rocket employing principles of real lifting bodies.

THEORY

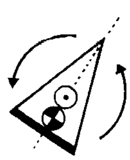
1. A falling piece of plain paper will not plummet straight to the ground like a rock. It tumbles and slips from side to side in an unpredictable and unstable flight path.



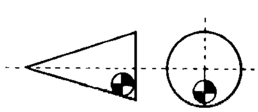
2. Now the paper is rolled into a cone shape. It will fall fairly straight, point first.



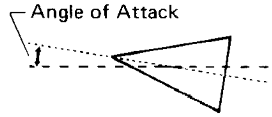
3. The cone's center-of-gravity (balance point) is ahead of its center-of-pressure (theoretical point where all aerodynamic forces seem to converge).



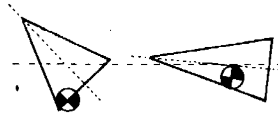
4. Adding a heavy circular base to the cone moves the CG behind the CP. The cone's shape makes it try to streamline in, but the rearward weight makes it try to fall tail first. These forces "fight" each other, and cause the cone to tumble as it falls.



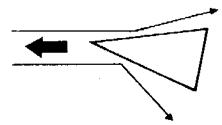
5. These two forces can be made to cooperate by moving the weight to one side, at the cone base.



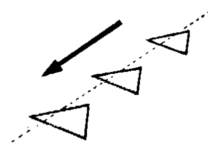
6. When the correct amount of weight is used, the nose cone will fall through the air with the nose pointing up, at a slight angle (called the angle of attack).



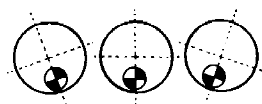
7. By moving the CG toward or away from the point of the cone, the angle of attack can be increased or decreased.



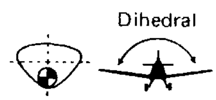
8. The cone moves through the air, creating resistance, or drag. The bottom surface is at a greater angle of attack than the top surface, therefore the bottom surface meets more air resistance.



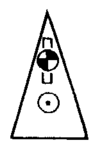
9. The cone "rides" this air resistance down at a gradual angle, like a sled coasting downhill. This is a form of flat plate lift. While not as efficient as an airfoil, it allows a gradual, safe descent.



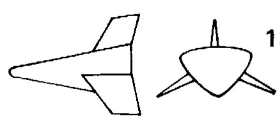
10. The cone still has a tendancy to sway or roll from side to side as it descends.



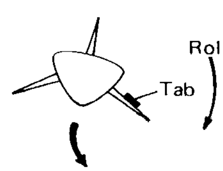
11. Changing the cone's cross section to a semi-triangular shape helps avoid roll. This is similiar to the dihedral of airplane wings . . . the craft "settles" into a neutral middle position.



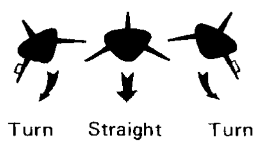
12. Placing the model rocket engine in the front of the cone makes it very stable in upward flight. CG is well ahead of CP.



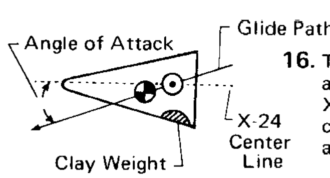
13. Fins are unnecessary for a gliding return. However addition of fins will stabilize the cone at engine ejection, and prevent it from being thrown end over end.



14. Bending up a tab on one wing creates drag on that side causing cone to roll. The roll causes the Bug flight path to veer towards tabbed side.

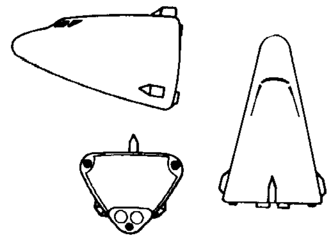


15. By rolling the cone in flight, cone can be steered to right or left. Tabs can also be used to cancel tendency to turn.



16. The engine ejects, causing the CG to shift down and to the rear. In glide configuration, the X-24 remains stable (CG ahead of CP), but off center CG forces the X-24 to fly at a positive angle of attack.

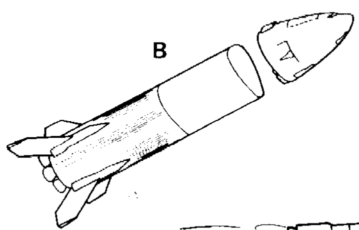
A REAL VEHICLE CONCEPT



The variable CG lifting body as a Space Shuttle Orbiter

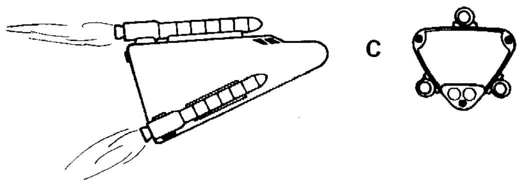
A NASA's lifting body tests may lead to Shuttle Craft for bearing men and supplies to orbiting space stations. A real Space Shuttle patterned after our lifting body model might have some important advantages.

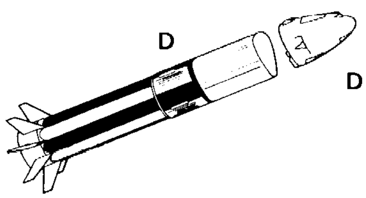
By the use of roll jets and a moving weight system, the lifting body could be controlled in both yaw and pitch.



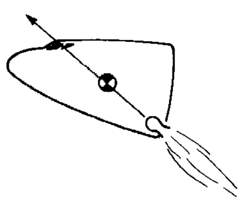
B A large Apollo Little Joe type of rocket could boost shuttle craft for suborbital tests.

C Or the shuttle could be boosted by a cluster of large segmented solid fuel boosters.

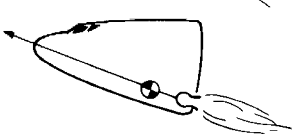




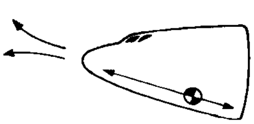
D A modified Saturn 1B could give the lifting body orbital capability. Or, a Space Shuttle type of "mother ship" could be used for greater economy.



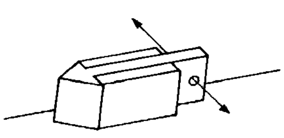
E At 40 miles up and 2800 miles per hour, the fully loaded shuttle (with its rocket engine mounted at the lowest point of the cone base) "crabs" at a negative angle of attack. In a vacuum this poses no problem.



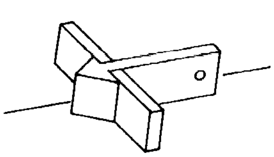
F With fuel almost gone, the shuttle's angle of attack approaches zero. Note that the rocket motor must thrust through the CG if the shuttle is to fly a straight course.



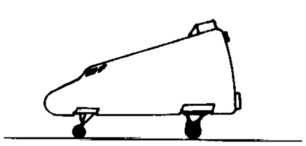
G Running along the belly of the shuttle, a sliding weight (not necessairly inert, perhaps one of the shuttle subsystems) changes the CG for pitch control during the gliding return.



H Reaction thrusters in small fins provide attitude control in zero G and yaw control during re-entry.



I Drag flaps extend from pods for control during subsonic glide. In both cases, movement to the right or left is accomplished by rolling the shuttle in flight so that the shuttle's built-in lift pulls to one side or the other.

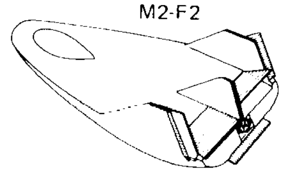


J The returning craft lands on conventional runways. Like an airliner, it will be prepared for more flights.

LIFTING BODY FLIGHT TEST VEHICLES*

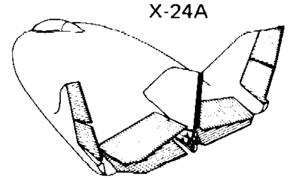
Here are three of the more famous actual lifting bodies tested by the U.S. Air Force and National Aeronautics and Space Administration.

M2-F2



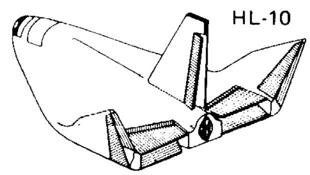
Body Planform Area, ft.	160.0
Body Span, ft.	9.5
Body Length, ft.	22.0
Landing Weight, lb.	6150

X-24A



Body Planform Area, ft.	191.0
Body Span, ft.	13.5
Body Length, ft.	24.5
Landing Weight, lb.	6000

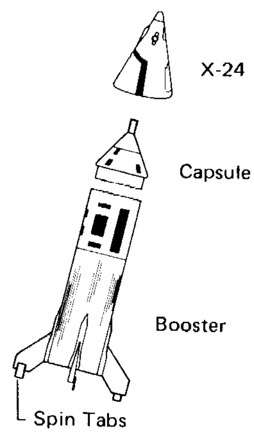
HL-10



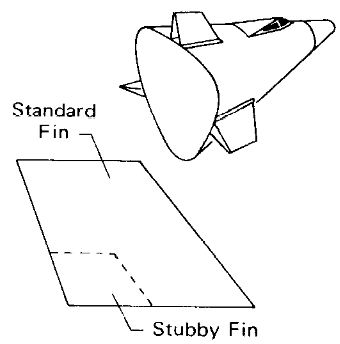
Body Planform Area, ft.	160.0
Body Span, ft.	14.5
Body Length, ft.	22.0
Landing Weight, lb.	6400

*Data and illustrations courtesy of American Institute of Aeronautics and Astronautics, AIAA Paper No. 71-310.

EXPERIMENTS WITH THE FINLESS X-24



The X-24 has been successfully flown without its stabilizer fins. At the peak of most finless flights, the ejection charge pushes the X-24 ahead so fast that it stalls and flips end over end. However, once in a stable glide, the X-24 is stable on all axes and glides well, sometimes rocking gently as it makes its descent. For higher and more dependable flights, the finless X-24 can be carried by a modified Centuri 1/45 scale Little Joe II. Simple paper spin tabs are added to one side of each fin to increase stability. The kit is built with 2" of #5 tube protruding from the capsule, instead of adding ladders and tower. The X-24 fits over the #5 tube, its base resting on the Apollo capsule. At chute ejection, the X-24 simply drops away and glides back.



SEMI-FINLESS BUG: The X-24 Bug type of model rocket lifting body may be modified for greater endurance and durability. The substitution of much smaller wings and tail will produce a vehicle with less frontal area, allowing greater altitude in the rocket-powered ascent. Generally, the body will glide for a longer time from the higher apogee. The shorter, stubbier fins also withstand landing impact better. The addition of a little more rearward weight will cock the body's nose up to give longer, more gradual gliding returns.

REFERENCES FOR FURTHER STUDY

ABOVE AND BEYOND Encyclopedia of Aviation and Space Sciences
New Horizons Publishers, Chicago

1970 UNITED STATES AIRCRAFT, MISSLES AND SPACECRAFT
National Aerospace Education Council, Washington D.C.

X **NASA FACTS: LIFTING BODIES Vol. 4, No. 2**
U.S. Government Printing Office, Washington D.C.

WINGED ROCKETRY
Maj. James C. Sparks. Dodd, Mead & Co, New York