FLIGHT TEST DEVELOPMENT OF A NEW GENERIC CONFIGURATION
THE BOOMERANG (Part 1)

By Burt Rutan (M), Scaled Composites
Michael W. Melvill (M), Scaled Composites

The Boomerang (Figure 1) is a new high performance pressurized 5 place light twin intended for personal transportation. Its basic goals were to provide optimum performance from two turbocharged 200 hp Lycoming reciprocating powerplants. Probably one of the most difficult tasks faced in the development of this aircraft was explaining why I would design a configuration that is asymmetric. In fact, an early comment as the aircraft arrived at the Experimental Aircraft Association International Air Show at Oshkosh, Wisconsin this year, was from a fellow who ran up and remarked, "What in the hell were you smokin' when you laid that one out?" I found it difficult, if not impossible, to explain to this gentleman why I had designed an asymmetric airplane. However, on the assumption I will be more successful in describing those reasons to an astute technical audience here at the SETP Symposium, I plan over the next few minutes to describe the reasons I built so bizarre an aircraft.

![Boomerang Diagram]

<table>
<thead>
<tr>
<th>Figure 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boomerang Model 202</td>
</tr>
<tr>
<td>Five Place Pressurized Engines 200/210 BHP Gross Weight 4300 lb</td>
</tr>
<tr>
<td>Empty Weight 2480 lb Fuel 1007 lb Cruise 265 KTAS 1530 NM</td>
</tr>
</tbody>
</table>
Possibly the best way to describe the evolution of the Boomerang is to start with a conventional light twin and then, step-by-step, add improvements. The Baron 58-P (Figure 2) is the closest light aircraft to the performance and utility of the Boomerang.

### Figure 2

**Baseline Baron 58P**

<table>
<thead>
<tr>
<th>Span</th>
<th>37.8 ft.</th>
<th>Wing area</th>
<th>188 sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vert Area</td>
<td>24.4 sq.ft.</td>
<td>Total BHP</td>
<td>650</td>
</tr>
<tr>
<td>Useful Load</td>
<td>2222 lb</td>
<td>Max Fuel</td>
<td>1140 lb</td>
</tr>
<tr>
<td>Stall</td>
<td>78 kt</td>
<td>Cruise (75% 20kft)</td>
<td>224 kt</td>
</tr>
<tr>
<td>Stab area</td>
<td>56 sq.ft.</td>
<td>Empty Weight</td>
<td>4018 lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gross Weight</td>
<td>6240 lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (75% 20kft)</td>
<td>975 nm</td>
</tr>
</tbody>
</table>

While this aircraft looks symmetrical in its layout, aerodynamically it is not symmetrical because the P-effect at lower speeds moves the thrust lines of both engines to the right, resulting in the right engine being critical and right rudder being required at low speeds even with symmetrical power application. Figure 3 addresses that issue by moving the left engine further outboard, making a small lateral shift in the aircraft's CG. Now both engines provide the same minimum control airspeed. This modification also improves the cabin noise by moving the propeller further from the fuselage. This slight improvement to the aircraft has not improved its safety as the minimum control speed is well above stall and this characteristic has resulted in numerous out-of-control accidents following engine failures.
Left engine moved outboard to improve symmetry at low speeds and to reduce cabin noise.

The next iteration (Figure 4) reduces the minimum control speed by moving both engines inboard, closer to the lateral CG. This necessitates moving the right engine well forward to keep the propeller from hitting the fuselage. To balance the aircraft longitudinally, the left engine is moved aft. This aircraft, of course, has some structural problems in supporting these grossly skewed engines, so Figure 5 addresses that by merely skewing the wing to provide better support for the right engine and less aerodynamic interference for the left engine.

Both engines moved inboard to reduce MCS. Right engine moved forward to clear fuselage. Left engine moved aft to balance.

Wing skewed to support engines and to reduce left engine interference.
The next major improvement to make to this aircraft involves making its entire structure from carbon fiber composites (Figure 6).

![Composite construction allows smaller, higher aspect ratio wing, but configuration is now nose-heavy, thus left wing is swept forward. This helps, but configuration is still nose-heavy.](image)

This results in a lighter structure allowing a smaller, higher aspect ratio wing. The configuration is now nose heavy which is somewhat addressed by sweeping the left wing forward. The left wing is now the same sweep as the right wing which will provide near symmetrical stall characteristics. The forward sweep of the left wing is inadequate to fix the nose heavy condition, so a step is taken which is rarely done in the evolution of aircraft and that is to put in smaller, lighter engines (Figure 7). The aircraft now balances longitudinally, the tail area can be reduced, and its aspect ratio increased. The long, slender fuselage and high aspect ratio tail presents a problem for flutter, and this is solved by Figure 8 in which the nacelle of the left engine is extended to support the high aspect ratio horizontal tail surface. This improvement also provides unpressurized baggage in the left boom. It is now recognized the airplane can be further improved performance-wise by decreasing the wetted area and the structural parts count by merely moving the right engine to the nose of the fuselage. This moves the lateral CG further left. This is compensated by merely sliding the entire wing to the left. The CG now resides to the left, but still within the fuselage structure. This aircraft now has the engines so close together that the propellers overlap and we find that the minimum control speed is considerably below stall (Fig. 9).
Figure 7
The weight savings allows smaller engines and tail area can be reduced.

Figure 8
High aspect ratio tail flutter problem is fixed with nacelle boom. This allows additional baggage room in boom.

Figure 9
Right engine is moved to the fuselage to reduce weight, cost and drag. Lateral balance is restored by moving entire wing to the left. MCS is now well below stall.
FLIGHT TEST DEVELOPMENT OF A NEW GENERIC CONFIGURATION
THE BOOMERANG
(Part 2)

By Burt Rutan, Scaled Composites
Michael W. Melvill, Scaled Composites

The next iteration (Figure 10) moves the left engine well outboard to reduce the cabin noise and eliminate the propeller interference. This moves the CG outside the fuselage to the left. The wing is again translated to the left to restore the lateral balance. The resulting aircraft still has the minimum control speed below stall for low speed safety. The next iteration (Figure 11) involves replacing the Baron's enormous vertical fin with two small ones, thus resulting in drag and weight savings and allowing the fuselage to be recontoured at the aft to a pressure recovery, low drag shape.

Figure 10
Left engine is moved outboard to reduce cabin noise and to eliminate prop interference. Entire wing is moved left to restore lateral balance.

Figure 11
Twin small vertical tails improve low speed handling, reduce weight and allow low-drag pressure-recovery aft fuselage.

Figure 12 completes the evolution by using a round fuselage for increased room and better weight savings with pressurization, providing laminar flow flying surfaces with full span camber control, which allows laminar flow to occur at a variety of lift coefficients. The wing area is further reduced to increase the wing loading. This results in more comfortable turbulence ride and higher cruise performance. We now find we are able to use an aspect ratio of 13.2, whereas the standard configuration was limited to less than 7. Figure 13 summarizes what happens due to all these changes and shows a higher performance aircraft with considerably more range and efficiency.
Figure 12
Baron 58P
3.8psi cabin
6 seats
3% more span
84% more wing area
65% more tail area
59% more engine power
62% more empty weight
13% more fuel
45% more gross weight

Boomerang
4.6 psi cabin
5 seats or 4 seats+1 bed
15% wider cabin
20% longer cabin
92% more aspect ratio
10% higher stall speed
45% more climb rate
41 kt higher cruise speed
56% more range at 75%
92% more max range
Immune from MCS accidents

Figure 14 illustrates the cabin arrangement for the Boomerang. Note that all occupants are at separate fuselage stations, deconflicting the elbows, allowing considerably more comfort. The pilot is in the right seat, allowing the use of a right hand sidearm controller. The engine controls are blended into the armrest. Cockpit entry is via a plug door at the right windshield. The aft cabin houses three seats or, as shown in Figure 14, two seats and a bed. The unpressurized baggage area in the boom is 120 inches long, allowing carriage of skis, fishing poles, or other long cargo in addition to the normal baggage. A relatively large horizontal tail provides a very wide CG range, thus allowing baggage to be placed considerably aft.
Figure 14

**Boomerang Seating**

Pilot in right seat. Outboard sidesticks. Engine controls in armrest. Aft station is seat or bed.

Figure 15 shows the Boomerang fuselage structure which is unique in that the entire structure shown, including all of its reinforcements, bulkheads, longerons, windshield frames, engine mounts, gear doors and entry doors were constructed in a modified filament wound procedure in which the entire structure is a single cure. The structure shown was built in less than 14 hours.

Figure 15

Figure 16 illustrates the unusual instrument panel of the Boomerang. All engine instrumentation, GPS moving map navigation, flight management and other functions are dedicated to an off-the-shelf Macintosh Powerbook® notebook computer. This leaves the instrument panel relatively barren and allows a large glove box. The notebook computer provides archiving of all flight data at a low baud for the entire life of the aircraft rather than the last 50 minutes or so which is recorded on commercial airliners.
During the entire life of the Boomerang, the basic flight data, engine data, etc. are automatically logged on a labeled file on the Powerbook's hard disk. The system also continuously buffers, at high baud, the last 60 seconds of time. Thus, any time the pilot wants to record flight test instrumentation, he merely waits until after the event and then, with a "Command S", the computer dumps this information onto a labeled file. Thus, for the life of the aircraft, there is an always running flight test instrumentation system. Another thing that is handy is that the Powerbook's hard disk includes all of the aircraft's drawings, vendor data, pilot's flight log and maintenance records, integrated in such a way that expert software can manage many of the pilot's tasks. The airplane continuously monitors and displays lift coefficient, angle of attack, time and distance to fuel exhaustion, recommended reflex position, and literally anything you want calculated. (We're still debugging the "Cooper rating" calculation!)

Figure 16

Figure 17 illustrates the airplane's unusual planform. The entire trailing edge of the wing, exclusive of the center portion, serves as an aileron, landing flap, and camber control. This allows the aircraft to optimize the wing's efficiency, from climb speed to high speed cruise or at any lift coefficient in between.

Figure 17
Unlike most aerospace companies, at Scaled Composites, it is not unusual to flight test a new configuration that has no wind tunnel or simulation experience. One of the procedures used to ensure that on the first flight, the safety of the test pilot is enhanced by bringing along the designer of the aircraft (Figure 18). The Boomerang's test program began with high speed taxi and runway liftoffs on June 14, 1996 and a formal first flight on June 19. The aircraft's handling, surprisingly, was excellent. The pilot could perceive no asymmetric characteristics in spite of the unusual configuration. Inadequate oil cooling on the left engine, however, resulted in an early return to base and landing which resulted in disaster! Due to a rigging error, the left main landing gear retracted upon touchdown the aircraft slid along on the left wingtip and boom. This resulted in one of the two right main gear tire/brakes to be suspended above the runway. With only one of four brakes available, the brake faded and the aircraft slid off the runway, resulting in major damage to the nose gear, right main gear, both propellers and cowlings (Figure 19). Even without government funding, a small team can spring to action and recover quickly! Within 22 days of the accident, the airplane was back in flight test status and has completed the remainder of its test program without incident.
FLIGHT TEST DEVELOPMENT OF A NEW GENERIC CONFIGURATION
THE BOOMERANG
(Part 3)

By Burt Rutan (M), Scaled Composites
Michael W. Melvill (M), Scaled Composites

The remainder of this report consists of a presentation of the flight test data with emphasis on the airplane's unique, lateral/directional configuration and characteristics. All the data was gathered by the aircraft's Powerbook "instrument panel" data system and processed on Excel spreadsheets. Figure 22 shows the static longitudinal characteristics including the effects of power. The aircraft has normal, stable longitudinal stability with noseup trim change due to power. Figure 23 compares the forward and aft CG static longitudinal data. The unusual shape of the curve at midspeed is not noticed by the pilot. The cause of this nonlinearity in the longitudinal data is not yet known.

Figure 22
Static Longitudinal Stability & Thrust Trim Change
Aft CG
Boomerang M202 8Sep95 flt

![Graph showing static longitudinal stability and thrust trim change.](image)
In order to assess the aircraft's lateral/directional asymmetry, the aircraft was trimmed at a minimum speed of 160 knots, accelerated to high speed, decelerated to minimum speed (full aft stick, 78 KCAS). This maneuver was flown with constant symmetrical cruise power and the pilot's feet on the floor with no rudder inputs (Figure 24). Aileron was used to keep the aircraft's flight course constant. Aileron position changed approximately 2°, most of the change occurring in the mid speed range. In spite of the small control inputs, the aircraft exhibits a quarter ball, lateral acceleration at 120 kt and a half ball at the minimum speed of 78 knots. It should be noted that this asymmetry is due mainly to the propeller thrust P-effects, rather than the airplane's asymmetric configuration. Tests with a conventional "symmetrical" configuration medium twin showed the same low speed asymmetry with symmetrical cruise power.
Figure 25 illustrates the control deflections required if the pilot flies the same maneuver, this time using the rudder to center the ball and the aileron to hold the flight course. In order to center the ball at low speeds, a significant rudder deflection is required, approximately 10° at the minimum full aft stick speed of 77 kt. This maneuver seems less normal to the pilot at low speeds even though aileron deflections are still small, the bank angle is changed about 3° and requires more pilot workload than merely leaving the feet on the floor.

![Figure 25](image)

**Figure 25**
Static Trim Requirements
Symmetrical Cruise Power
Ball Centered

![Graph](image)

Figures 26 and 27 illustrate that these characteristics are not a function of power intensity. The same rudder and aileron deflections are required to center the ball at all speeds, regardless of power ranging from idle to full takeoff power. The majority of change of aileron requirements occurs between 140 and 160 kt (Figure 26). This is not noticed by the pilot and has yet to be explained by the designer.

![Figure 26](image)
Figure 27 illustrates the basic lateral directional control requirements in a steady forward slip. The abscissa is a "derived" sideslip angle, since the aircraft is not instrumented with a beta vane. This was done by flying a neutral rudder and full rudder sideslip, holding a constant GPS course, noting the aircraft's nose position on a horizon mountain, then changing course to that direction and noting the new GPS course. This method is relatively effective in estimating maximum sideslip without a vane. The data in Figure 28 thus assumes that rudder position is linear with sideslip angle. Lateral characteristics are conventional, reasonably symmetrical, show a light but positive dihedral effect, and phi to beta ratio of approximately one (1).
Now for the fun stuff -- the engine-out handling. Safe engine-out handling via configuration design was a major design driver in the Boomerang's unusual configuration. All data in Figures 29, 30 and 31 are for one engine out (feathered or zero thrust) and the opposite engine at full rated takeoff power. Figure 29 represents 4 separate engine-out maneuvers, two performed with the pilot attempting to center the ball with the rudder pedals and two with the pilot merely placing his feet on the floor. The first thing one notices about Figure 29 is that considerably more rudder is required for a left engine inoperative condition than a right engine inoperative condition. This is backward from what one may expect for an airplane that has the left engine at BL -56 and the right engine at a BL of only +32. Significantly, the P-effect or other fuselage interference effects overrides the expected asymmetry such that the airplane's critical engine is the left, not the right. Of course, the airplane doesn't really have a critical engine because it is possible to fly at the minimum full aft stick speed of the 77 kt without loss of control. Of course, what is more interesting is that the aircraft was able to achieve the same minimum speed with engine out with the pilot's feet on the floor not even touching the rudder pedals! Figure 30, data for the same four maneuvers as Figure 28, illustrates the aileron requirements. Note that when the pilot uses the rudders to center the ball, very little aileron activity is required to maintain course even though maximum power asymmetry is being applied. What is even more unusual is that when the pilot's feet are placed on the floor and the aircraft is slowed to minimum speed with asymmetric power, only about 2° of aileron deflection is required to maintain course. In all cases, engine-out handling is more "normal" and "comfortable" to the pilot if he merely places his feet on the floor and does not attempt to do anything with the ball. Surprisingly, with either engine out, the airplane can be flown right to the stall speed holding course with the pilot's feet on the floor and a small aileron deflection applied.

Figure 29
Engine-Out Rudder Requirements
Boomerang M202 15Sep85 ft

![Diagram of Engine-Out Rudder Requirements](image-url)

- Lt Engine Inop Ball Centered
- Rt Engine Inop Ball Centered
- Lt Engine Inop Feet-on-Floor
- Rt Engine Inop Feet-on-Floor

Calibrated Speed ~ KCAS

Rudder Position ~ deg

60 70 80 90 100 110 120 130 140

0 5 10 15 20
After achieving this unusual result, we questioned what would happen to a normal light twin if the pilot decided not to use the rudder pedals in an engine-out flight condition. The data in Figure 31 illustrate that comparison. The upper graph in Figure 31 is two separate maneuvers showing the rudder required for a Beechcraft Duchess and the Boomerang during a maneuver in which the pilot is attempting to center the ball with the rudder pedals. The Duchess reaches full rudder at 112% of the stall speed, its minimum control speed. The Boomerang uses approximately 80% of its rudder to center the ball at the stall speed of the aircraft. For both these maneuvers, the aileron requirements were relatively small -- less than 10% of authority. The lower graph of Figure 31 is data for completely different type of maneuvers. For these maneuvers, the Duchess and Boomerang were flown asymmetric thrust with the pilot’s feet on the floor, not touching the rudder pedals. Here a dramatic difference is observed. The Duchess’s minimum control speed is raised 12% in a very uncomfortable maneuver resulting in large bank with full aileron and the pilot is strongly desirous of using the rudder pedal. The Boomerang, on the other hand, trims at minimum speed, full aft stick, feet on the floor with a small percentage of the aileron control being required.
Figure 31
Engine-Out Control Requirements Comparison
Boomerang vs Beech Dutchess
Right Engine Max, Left Engine Feathered

- Dutchess-normal technique
- Boomerang-ball centered

Rudder Required
% of Full Rudder

Aileron Required
% of Full Aileron

Calibrated Speed % of stall speed
Figures 32 and 33 compare the Boomerang's performance to other aircraft in its class. The Boomerang represents large increases in efficiency and range over the conventional aircraft.

Figure 32
Range & Speed Comparison
Cruise at Best Altitudes

- Baron 58P 6 seats 870 lb fuel
- Baron 58P 4 seats 1140 lb fuel
- Boomerang 5 seats 1008 lb fuel
- Deliant 4 seats 650 lb fuel
- Malibu 6 seats 708 lb fuel
- Cessna 421 6 seats 1450 lb fuel
- Dutchess 4 seats 590 lb fuel
- KingAir C90 6 seats 2265 lb fuel
Figure 33, Efficiency & Speed Comparison
Cruise at Best Altitudes

Figure 34, a photograph of 3 completely different solutions to a light twin's configuration: 1) the conventional engines on wing; 2) the push/pull Defiant; 3) the Boomerang. The Boomerang represents a significant increase in performance and efficiency, excellent general flying qualities and engine-out safety. Its configuration is clearly superior to the other two. Is this the optimum configuration for light twins? Who knows. Maybe we will think of a better one later. If so, we hope it will be as fun to fly as the new Boomerang!