

COMBINED WHITE KNIGHT / SPACESHIPONE FLIGHT TESTS

Combined Flight Test Legend: C = Captive Carry
L = Launch
G = Glide
P = Powered

The first letter represents the intended mission for the flight and the second letter, if present, represents the actual mission flown. For example, first glide will for the space ship will be 03G. If the flight aborts or doesn't release for whatever reason, the nomenclature becomes 03GC.

Flight: 66L / 17P
Date: 04 Oct 04
Flight Time 1.6 hr / 24 min
WK Pilot: Melvill **WK CoPilot:** Stinemetze
SS1 Pilot: Binnie
High Chase Alpha Jet Crew: Van der Schueren / Johnson
High Chase-Starship Crew: Karkow / Scherer
Low Chase-Extra Crew: Coleman / Bird

Objectives:

Second X-prize flight: again ballasted for 3 place & 100 kilometer goal (328,000 ft)
(We also really wanted to break the X-15 354 kft record)

Results:

A very large crowd of dignitaries and X-prize guests...along with a whole lot of local folks cheered the White Knight turbojet with SS1 tagging along to a 6:49 a.m. PST takeoff. The launch altitude this flight was 47,100 feet. At 7:49 a.m. PST, flight engineer Matt Stinemetze released the spaceship and test pilot Brian Binnie immediately fired the hybrid rocket motor. This ignition was so quick that Mike & Matt actually heard the rocket burn from inside the WK. The rocket burn lasted for 83 seconds boosting the vehicle to more than 3.09 Mach or 2186 miles an hour. At motor burn out, SpaceShipOne was at 213,000 feet and from there coasted the rest of the way into space reaching an apogee of 367,500 (radar) feet (112 Km). Brian feathered the spaceship as dynamic pressure approached zero during ascent. Like Mike on 16P, Brian used a digital camera to shoot pictures (one of Brian's photos later appeared on the cover of Aviation Week). He also conducted a series of zero-g experimental flight tests of a small paper SpaceShipOne model. Binnie experienced weightlessness for approximately 3 ½ minutes as the vehicle slowly decelerated to apogee, and then began its fall towards the atmosphere. Maximum Mach during entry was 3.25. During the descent, the pilot experienced a peak deceleration of 5.4 G's at about 105kft altitude. Brian reconfigured the vehicle back to a glider by commanding feather retraction at 51,000 feet and over the next 18 minutes enjoyed a leisurely descent to a graceful landing at Mojave, thus closing the book on our Tier One program. This historic flight not only broke the X-15 record by 13,000 ft, and won the X-prize, but was a picture perfect ending to the program. No anomalies were noted on the flight and SpaceShipOne returned with no maintenance squawks. This last Tier One flight was a testament to what training and good old-fashioned hard work can do.

The 13 month, 17-flight SpaceShipOne flight test program included just six rocket powered flights, three of which flew to space (above 100 Km). In comparison, the X-15 program (which included 3 test aircraft) took 3 years 4 months, and 110 flights to reach 50 miles altitude (80.5 Km), and 4 years 4 months to reach Space (100 Km altitude).



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 65L / 16P
Date: 29 Sep 04
Flight Time 1.6 hr / 24 min
WK Pilot: Binnie **WK CoPilot:** Stinemetze
SS1 Pilot: Melvill
High Chase Alpha Jet Crew: Van der Schueren / Johnson
High Chase-Starship Crew: Karkow / Scherer
Low Chase-Extra Crew: Coleman / Bird

Objectives:

First X-prize flight: ballasted to simulate 3 place, & to exceed 100 kilometers (328,000 ft)

Results:

Greeted early in the morning by thousands of eager X-prize onlookers, the White Knight turbojet launch aircraft took off at 7:12 a.m. PST, carrying SpaceShipOne under its fuselage to an altitude of 46,500 feet. At 8:10 a.m. PST, flight engineer Matt Stinemetze released the spaceship and test pilot Mike Melvill quickly fired the hybrid rocket motor. The rocket burn lasted for 77 seconds, boosting the vehicle to more than 2.92 Mach or 2110 miles an hour. At motor burn out, SpaceShipOne was at 180,000 feet and from there it coasted the rest of the way into space reaching an apogee of 337,700 (radar data) feet (103 Km). At 60 seconds into the burn, very large roll-rates were experienced (see description below). The vehicle entered into a right rolling ascent at an initial average roll rate of 190 °/sec. Since the ship was in thin air and quickly leaving the atmosphere, it was not possible to stop the rolls using only aerodynamic flight controls. Melvill did input aerodynamic corrective controls and was able to lower the roll rate to 140°/sec before leaving the atmosphere. Later, after feathering the wing/tail, he used the reaction control system (RCS) to damp the roll rate. Mike was able to completely remove the rates before reaching apogee. He then used a hand-held digital camera to shoot some pictures out the windows. Melvill experienced weightlessness for approximately 3 ½ minutes. The supersonic feathered atmospheric entry was smooth, with only small oscillations. During the descent the spaceship accelerated to Mach 3.0. At max q, approximately 105kft altitude, Mike experienced a peak deceleration of 5.1 G's. Mike reconfigured the vehicle back to a glider by commanding feather retraction at 61,000 feet and over the next 18 minutes enjoyed a leisurely descent to a graceful landing at Mojave, the Nation's first inland Space Port. Mike now holds the world record for the most aileron rolls during a vertical climb! :) SpaceShipOne returned with no maintenance squawks.

SpaceShipOne Flight 16P Anomaly:

Highly publicized in the media, the rolls near the end of the motor burn certainly got our attention. Detailed analysis determined that the rolls resulted from a mild thrust asymmetry, which was unable to be offset by pilot inputs at a flight condition of low directional stability. This flight condition had not been tested on previous flights. The low directional stability occurs only at high mach #'s and at very low (zero or negative) angles of attack. On earlier flights the aircraft still had some lift at high mach numbers and did not approach the low angle of attack regime. On 16P, because Mike did such a great job of turning the corner early in the burn, the later segments of the burn had to be at near zero lift to point the trajectory in the desired direction. At this condition around mach 2.7 the airplane was excited in yaw and then the high dihedral effect resulted in a rolling departure from controlled flight. The fix to this problem that allowed a smooth boost 5 days later on 17P, was to fly a slightly less aggressive initial pull-up. This allowed Brian to avoid the low angle of attack regime when at high Mach. The characteristics of excessive dihedral effect and high-Mach low directional stability will be corrected on future spaceship designs.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 60L / 15P
Date: 21 Jun 04
Flight Time 1.6 hr / 24 min 05 sec
WK Pilot: Binnie **WK CoPilot:** Stinemetze
SS1 Pilot: Melvill
High Chase Alpha Jet Crew: Van der Schueren / Johnson
High Chase-Starship Crew: Karkow / Scherer
Low Chase-Extra Crew: Coleman / Bird

Objectives:

First commercial astronaut flight by exceeding 100 kilometers (328,000 ft)

Results:

Cheered down the runway by onlookers, the White Knight turbojet launch aircraft took off at 6:47 a.m. PST, carrying SpaceShipOne under its fuselage to an altitude of 47,000 feet. At 7:50 a.m. PST, flight engineer Matt Stinemetze released the spaceship and test pilot Mike Melvill immediately fired the hybrid rocket motor. The rocket burn lasted for 76 seconds, rocketing the vehicle to more than 2.9 Mach or 2150 miles an hour. At motor burn out, SpaceShipOne was at 180,000 feet and from there coasted the rest of the way into space reaching an apogee of 328,491 feet. Melvill experienced weightlessness for approximately 3 ½ minutes as the vehicle slowly decelerated to apogee and then yielding to the pull of gravity commenced its historic return to earth in the craft's unique entry or feathered configuration. During the descent the pilot experienced forces greater than 5.0 G's as the vehicle accelerated again to 2.9 Mach. Melvill reconfigured the vehicle back to a glider at 57,000 feet and over the next 20 minutes enjoyed a leisurely descent to a graceful landing at Mojave, the Nation's first inland Space Port.

SpaceShipOne Flight 15P Anomaly:

As mentioned in the post-flight press conference, during SpaceShipOne's historic flight to 100 kilometers on 21 June 2004 there was a flight control malfunction. Late in the boost phase, the vehicle's primary pitch trim control was lost. Scaled views any flight control system anomaly as a serious matter, but to guard against these problems, the vehicle has redundancy on all flight-critical systems, including pitch trim. So when the failure occurred, test pilot Mike Melvill switched to the backup system and continued the planned mission. However, the resulting trajectory excursion had two effects. One, the vehicle didn't climb as high as planned and two, the space ship re-entered south of the intended recovery point. This latter effect, while undesirable, was well within the vehicle's glide capability and SpaceShipOne had no difficulty flying back to Mojave Space Port for a normal landing.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 56L / 14P
Date: 13 May 04
Flight Time 1.5 hour / 20 min 44 sec
WK Pilot: Binnie **WK CoPilot:** Stinemetze
SS1 Pilot: Melvill
High Chase Alpha Jet Crew: Van der Schueren / Johnson
Low Chase-Duchess Crew: Siebold / Moore

Objectives:

The third powered flight of SpaceShipOne. 55 seconds motor burn time. Handling qualities during boost and performance verification. Reaction control system use for reorientation to entry attitude. Supersonic feather stability and control.

Results:

Launch conditions were 46,000 feet and 120 knots. Motor light off occurred 10 seconds after release and the vehicle boosted smoothly to 150,000 feet and Mach 2.5. Subsequent coast to apogee of 211,400 feet. During a portion of the boost, the flight director display was inoperative, however the pilot continued the planned trajectory referencing the external horizon. Reaction control authority was as predicted and the vehicle recovered in feather experiencing 1.9M and 3.5G's. Feather oscillations were actively damped by the pilot and the wing was de-feathered starting at 55,000 feet. The onboard avionics were re-booted and a smooth and uneventful landing made to Mojave.

Flight: 53L / 13P
Date: 08 Apr 04
Flight Time 1.3 hr / 16 min 27 sec
WK Pilot: Binnie **WK CoPilot:** Stinemetze
SS1 Pilot: Siebold
High Chase Alpha Jet Crew: Van der Schueren / Johnson
High Chase-Starship Crew: Karkow / Scherer
Low Chase-Extra Crew: Melvill / Coleman

Objectives:

The second powered flight of SpaceShipOne. 40 seconds motor burn time. Handling qualities during boost, through transonic and supersonic. Reaction control system functionality in-flight and feather configuration stability during transonic re-entry. Evaluation of radar tracking capability.

Results:

Launch conditions were 45,600 feet and 125 knots. A planned immediate motor ignition was delayed about 2 minutes to evaluate a shock induced stall buffet resulting in an ignition altitude of only 38,300 feet. The 40 second rocket boost was smooth with good control. Pilot commented that the motor was surprisingly quiet; however the boost was heard by ground observers. Burnout occurred at 1.6M and apogee was over 105,000 feet. There was no noted flight control flutter or buzz during the climb. Feather recovery was nominal. Maximum feathered speed on entry was 0.9 Mach. The wing was de-feathered and locked by 40,000 feet. Handling quality assessments during descent were satisfactory and a smooth landing made to runway 30 at Mojave. All video and tracking systems performed well with spectacular footage obtained onboard, from chase, and from ground stations.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 49L / 12G
Date: 11 Mar 04
Flight Time 1.3 hr / 18 min 30 sec
WK Pilot: Binnie **WK CoPilot:** Stinemetze
SS1 Pilot: Siebold
High Chase-Starship Pilot: Karkow
Low Chase-Extra Crew: Melvill / Coleman

Objectives:

The twelfth flight of SpaceShipOne. Objectives included: pilot proficiency, reaction control system functionality check and stability and control and performance of the vehicle with the airframe thermal protection system installed. This was an unpowered glide test.

Results:

Launch conditions were 48,500 feet and 125 knots. All systems performed as expected and the vehicle landed successfully while demonstrating the maximum cross wind landing capability.

Flight: 43L / 11P
Date: 17 Dec 03
Flight Time 1.2 hr / 18 min 10 sec
WK Pilot: Siebold **WK CoPilot:** Bird
SS1 Pilot: Binnie
High Chase-Starship Pilot: Karkow
Low Chase-Extra Crew: Melvill / Coleman

Objectives:

The eighth flight of SpaceShipOne and first powered flight. 15 second burn of the rocket motor and supersonic flight. Motor light off at altitude and inflight engine performance. Vehicle handling qualities through transonics and feather performance from altitude.

Results:

Launch conditions were 47,900 feet and 112 knots. Motor light off was achieved at 44,400 feet and 0.55M. Burnout occurred at 1.2M and apogee was 67,800 feet. There was no noted flight control flutter or buzz during the climb. Feather recovery exhibited a +/-30 roll initially and then settled down into the familiar falling bathtub mode. The wing was de-feathered and locked by 35,000 feet. A nominal landing pattern was flown, but touchdown caused the left main gear to collapse and the vehicle rolled to a stop off the runway in the soft sand. Although the damage was not major, repairs are expected to take approximately three weeks to complete.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 42L / 10G
Date: 04 Dec 03
Flight Time 1.3 hr / 13 min 14 sec
WK Pilot: Siebold **WK CoPilot:** Stinemetze
SS1 Pilot: Binnie
High Chase-Starship Pilot: Karkow
Low Chase-Extra Crew: Melvill / Coleman

Objectives:

The seventh glide flight of SpaceShipOne and new pilot check out. Full functional check of the propulsion system by cold flowing nitrous oxide. Completed airspeed and positive and negative G-envelope expansion.

Results:

Launch conditions were 48,400 feet and 115 knots. All propulsion components, displays and functionality performed as designed. The feather was extended after a 4G pull-up to the vertical at 24,500 feet and rudder used to induce sideslip and yaw rates while "going-over-the-top." The vehicle recovered to a stable attitude and descent after only a single oscillation. The landing pattern was flown following established procedures resulting in a satisfactory touchdown.

Flight: 41L / 09G
Date: 19 Nov 03
Flight Time 2.1 hr / 12 min 25 sec
WK Pilot: Binnie **WK CoPilot:** Bird
SS1 Pilot: Melvill
High Chase-Starship Pilot: Siebold
Low Chase-Duchess Crew: Coleman / Stinemetze

Objectives:

The sixth glide flight of SpaceShipOne. Test pilot Mike Melvill's first flight with the enlarged tails. Emergency aft CG handling qualities evaluation and simulated landing exercise with the new tail configuration. Airspeed and G envelope expansion and dynamic feather evaluation.

Results:

Launch conditions were 48,300 feet and 115 knots. Satisfactory vehicle handling characteristics at the emergency CG limit. Melvill reported improved stability, improved control powers and improved stick forces throughout the flight profile. The feather was extended after a 3G pull-up to the vertical at 30,000 feet. The vehicle recovered to a stable attitude and descent after a few mild oscillations. The landing pattern was flown at a higher airspeed than previous flights which allowed for a more controlled flare and landing at the nominal touchdown point.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 40L / 08G
Date: 14 Nov 03
Flight Time 1.4 hr / 19 min 55 sec
WK Pilot: Binnie **WK CoPilot:** Stinemetze
SS1 Pilot: Siebold
High Chase-Starship Pilot: Karkow
Low Chase-Duchess Crew: Melvill / Coleman

Objectives:

The fifth glide flight of SpaceShipOne. New pilot checkout flight. Stability and control testing with the new extended horizontal tails. Tests included stall performance at aft limit CG and evaluation of the increased pitch and roll control authority. Other objectives included additional testing of the motor controller (MCS) and handling qualities in feathered flight.

Results:

Launch conditions were 47,300 feet and 115 knots. Satisfactory stability and control at aft limit CG. A notable improvement in control power, particularly in roll. Handling qualities into and out of feather remained excellent with good nose pointing ability. Adjusted landing pattern altitudes resulted in a touchdown at the targeted runway aim-point.

Flight: 38L / 07G
Date: 17 Oct 03
Flight Time 1.1 hr / 17 min 49 sec
WK Pilot: Siebold **WK CoPilot:** Bird
WK FTE: Moore
SS1 Pilot: Melvill
High Chase-Starship Pilot: Binnie
Low Chase-Extra Pilot: Coleman

Objectives:

Fourth glide flight of SpaceShipOne. Primary purpose was to examine the effects of horizontal tail modifications at both forward and mid-range CG locations (obtained by dumping water from an aft ballast tank between test points). The tail modifications included a fixed strake bonded to the tail boom in front of the stabilator and a span-wise flow fence mounted on the leading edge of each stab at mid-span. (See the write up under the SPACESHIPONE GROUND TEST section that describes our Ford-250 wind tunnel which was used to help derive the current flight configuration). Other test objectives included a functional check of the rocket motor controller, ARM, FIRE and safing switches as well as the oxidizer dump valve. Additional planned maneuvers included full rudder pedal sideslips and more aggressive nose pointing while in the feathered configuration.

Results:

Launch conditions were 46,200 feet and 115 knots and produced a clean separation. The tail performance was examined by flying "longitudinal stability" points between stall and 130 knots and showed considerable improvement of the airfoil's lift coefficient as well as its post stall characteristics. No vehicle pitch up tendency was noted as the main wing now stalls first. Real time video of the tufted tails fed back down to mission control helped considerably in assessing the performance of these aerodynamic improvements. More aggressive maneuvering in the feather made it evident that the pilot could readily point the vehicle's nose where desired and all rocket motor functionality tests were satisfactory.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 37L / 06G
Date: 23 Sep 03
Flight Time 1.5 hr / 12 min 15 sec
WK Pilot: Siebold **WK CoPilot:** Stinemetze
WK FTE: Johnson
SS1 Pilot: Melvill
High Chase-Starship Pilot: Karkow
Low Chase-Duchess Pilot: Binnie

Objectives:

Third glide flight of SpaceShipOne. Aft CG flying qualities and performance evaluation of the space ship in both the glide and re-entry or "feather" mode. Glide envelope expansion to 95% airspeed, 100% alpha and beta and 70% load factor. More aggressive post stall maneuvering and spin control as a glider and while feathered. Nitrous temperature control during climb to altitude and performance of upgraded landing gear extension mechanism and space-worthy gear doors.

Results:

Launch conditions were 46,800 feet and 115 knots and produced a clean separation. First stall entry maneuver resulted in an un-commanded nose rise before reaching the wing stall angle of attack. Lateral/directional controls were used in conjunction with forward stick to effect recovery. This aft-cg stall characteristic was worse than predicted and will likely require aero modifications to fix. The feather entry was not explored and the rest of the glide flight used to assess the handling qualities of the vehicle leading to an uneventful landing. The White Knight's heating system was able to keep the space ship's nitrous oxidizer conditioned during climb, such that the maximum N2O pressure variation was less than 6 psi.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 32L / 05G
Date: 27 Aug 03
Flight Time 1.1 hr / 10 min 30 sec
WK Pilot: Binnie **WK CoPilot:** Bird
SS1 Pilot: Melvill
High Chase-Starship Crew: Siebold
Low Chase-Duchess Pilot: Karkow

Objectives:

Same objectives as the aborted flight 31LC/04GC earlier today. Second glide flight of SpaceShipOne. Flying qualities and performance in the space ship re-entry or "feather" mode. Pilot workload and situational awareness while transitioning and handling qualities assessment when reconfigured. As a glider, stall investigation both at high and low altitude and envelope expansion out to 200 kts and 4 G's. More aggressive, lateral directional characteristics including adverse yaw, roll rate effectiveness and control, including 360 degree aileron roll, and full rudder side slips.

Results:

Clean separation from launch at 48,200 feet and 105 knots, 8 miles north east of Mojave. First maneuver was a full stall, resulting in 70 KEAS at about 19 alpha. Good lateral control at minimum speed with ailerons and even better with rudder allowing timely control of roll-off tendencies. Second maneuver was unlocking the wing and commanding the full feathered mode (65 deg wing/tail jackknife). Transition to the feather mode occurred at 43,000 feet and 90 knots. As the tail booms and aft wing transitioned upward, the vehicle body smoothly pitched up and then returned to an approximately level pitch attitude during about 70 seconds of fully-feathered descent. The pilot noted the expected airframe buffeting and found the ship was very stable at an angle of attack of about 70 degrees. He was able to turn the vehicle both left and right with either rudder or aileron controls. As expected, full pitch control inputs had little effect on the flight path. Average sink rate was greater than 10,000 feet per minute. Reconfiguration back to the normal glider mode occurred at 30,000 feet with a positive wing lock indicated by onboard instrumentation and cameras. Third and fourth maneuvers were the airspeed and G envelope expansion which were flown without incident. Fifth maneuver was roll-performance, which resulted in a low amount of adverse yaw but lower roll rates than expected. Three-axis vehicle flight characteristics again showed close correlation to the vehicle simulator. Shifting winds at the field during later stages of the descent allowed the pilot to exercise the avionics' flexibility for landing cuing back to Runway 12 vice the planned runway 30 at Mojave. A smooth touchdown was made ten and a half minutes after launch. The video cameras mounted on the spaceship recorded dramatic views particularly during the unique feather maneuver. Observers in the chase Starship were treated to a closeup bizarre view of the spaceship plunging downward in a rock-stable near vertical feathered descent. First public showings of these videos will be on 26 September at the annual SETP symposium in Los Angeles.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 31LC / 04GC
Date: 27 Aug 03
Flight Time 1.1 hr
WK Pilot: Binnie **WK CoPilot:** Bird
SS1 Pilot: Melvill
High Chase-Starship Crew: Siebold
Low Chase-Duchess Crew: Karkow

Objectives:

Second glide flight of SpaceShipOne. Flying qualities and performance in the space ship feather mode. Pilot workload and situational awareness while transitioning and handling qualities assessment when reconfigured. As a glider, deep stall investigation both at high and low altitude and envelope expansion out to 200 kts and 4 G's. Lateral directional characteristics including adverse yaw, roll rate effectiveness and control including aileron roll and full rudder side slips.

Results:

The flight was aborted about 20 minutes before launch, after a GPS navigation malfunction occurred in the space ship avionics system. The mated pair continued to test other systems including space ship fuselage heating, then returned for a mated landing.

Flight: 30L / 03G
Date: 07 Aug 03
Flight Time 1.1 hr / 19 min
WK Pilot: Binnie **WK CoPilot:** Bird
SS1 Pilot: Melvill

Objectives:

First glide flight of SpaceShipOne.

Results:

The space ship was launched at 47,000 feet and 105 knots, 10 nm east of Mojave. Separation was clean and positive with no tendency to roll off or pitch bobble. An initial handling qualities evaluation was very positive, supported close correlation to the vehicle simulator and with that confidence, the first flight test cards were executed as planned. The flight provided handling quality and performance data over 60% of the expected subsonic flight envelope from stall to 150 knots. Trim sensitivity, stick forces, control harmony and L/D performance were all as expected. The onboard avionics and energy management cueing displays performed flawlessly, the gear extension rapid, and the vehicle made a smooth touchdown at 7:56 local on Runway 30 at Mojave. The entire flight, from launch to landing, was viewable from the ground and SpaceShipOne with its unique planform was intriguing to watch as it cut gracefully through the air and was put through its paces. See photos in the TierOne section. A special thanks to Robert Scherer, <http://www.bobscherer.com> for his flight test support and his beautiful Starship that provided primary chase for this milestone event.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 29C / 02C
Date: 29 Jul 03
Flight Time 2.1 hr
WK Pilot: Binnie **WK CoPilot:** Bird
SS1 Pilot: Melvill

Objectives:

First manned captive carry flight of SpaceShipOne. A man-in-loop launch rehearsal and inflight checkout of all ship systems including flight controls and propulsion system plumbing.

Results:

Complete full up rehearsal for SS1's first glide flight, including airspace, range control, Scaled mission control, data and video TM and high and low chase platforms. Providing high chase was one of Burt Rutan's earlier designs - the Starship, owned and operated by Robert Scherer. See accompanying photos in the TierOne media gallery section for the unique formation of the Starship, SpaceShipOne and White Knight. All SpaceShipOne's systems were exercised, including the environmental control, electrical, pneumatic and avionics. Flight control force versus displacement data was obtained to validate simulation modelling and even the space ship's feather control was exercised after cold soak at altitude. All systems performed satisfactorily including nitrous tank heating by White Knight bleed air and the pilot controlled N2O dump valve.

Flight: 24C / 01C
Date: 20 May 03
Flight Time 1.8 hr
WK Pilot: Siebold **WK CoPilot:** Binnie

Objectives:

First captive carry flight with mated White Knight and SpaceShipOne. Vibration and aerodynamic interface assessment. Mated handling qualities evaluation. Envelope expansion to 130 knots / Mach 0.5 above 45,000 feet. Stalls and 2/3-rudder sideslips. SpaceShipOne systems inactive, controls locked and cabin unmanned. Launch system was qualified and functional for this flight.

Results:

Excellent two-ship stability & control throughout the envelope. No interference or vibration issues. Smooth surface flows on SS1 except around rocket nozzle. Two-ship performance was as predicted. Mach .53 was achieved at 48,000 ft. Climb rate at 48,000 ft was 700 ft/min. Envelope was cleared for future manned captive carry and glide flights. Next flight should be a manned captive carry in which all SpaceShipOne systems (except rocket propulsion) will be tested at altitudes up to 50,000 ft. If successful, the glide flights will follow soon, since the systems preparation and pilot training requirements are the same.



SPACESHIPONE GROUND TESTS

The ground test program for SpaceShipOne, including rocket propulsion integration, has been active since the summer of 02. As of May 03, SpaceShipOne had completed most structural tests and systems qualification tests. Tests remaining to qualify the ship for glide testing are cabin pressure proof tests, some control system proof tests, additional landing gear functional tests and the GVT program. The following includes tests after mid May 03, updated periodically.

Test: Horizontal Tail Modification Aerodynamic Tests

Date: 08 Oct - 21 Oct 03

Objectives:

SpaceShipOne, being the first manned winged aircraft with outboard horizontal tails, is a bit of a pioneer. The outboard tail operating in an upwash flow-field is significantly more effective than a conventional tail. However, its span traverses the main wing's tip vortex and thus sees a non-uniform angle of attack. Our CFD analysis was not complete enough to predict the tail's airflow separation, which led to the nose rise departure during aft-cg stall testing (Flight 37L / 06G). In response, Scaled conducted full-scale "wind tunnel" tests of the SS1 boom-tail using a modified Ford-250 pickup truck to provide the necessary flow field. A couple pictures of the test set-up is shown in the photos section. The purpose of these tests was to examine various changes to SpaceShipOne's tail assembly to provide for better horizontal tail lift and tail lift-slope characteristics.

Results:

The testing conducted from 8 to 21 October successfully validated several aerodynamic fixes to solve the tail stall problem. The fixes were first flown on Flight 38L / 07G.

Test: System Tests

Date: 14 Jul - 24 Jul 03

Objectives:

System level qualification tests for several subsystems

Results:

Completed landing gear qualification tests, brake tests and low speed taxi tests. Required changing the nose skid material to prevent excessive wear. Finalized cabin proof pressure test and leak rate tests. Completed structural load tests of the horizontal stabilizer, flight control system and feather mechanism.

Test: System Tests

Date: 24 Jun - 09 Jul 03

Objectives:

To ensure the as-built systems meet the vehicle design requirements

Results:

Landing gear functional tests completed. Flight control system and structural qualification tests completed. Flight test data calibrations completed.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Test: Ground Vibration Testing (flutter qualification)

Date: 21 May - 23 May 03

Objectives:

To update the stiffness and mass distributions of the SpaceShipOne structural model so the analytical predictions match the actual vehicle frequency and modal response to a series of different forced vibrations. Since most flutter issues are critical for the rocket-powered flight tests, a rocket motor CTN was installed in SpaceShipOne for the GVT shake testing. The motor was one that had been fired for 15 seconds so its remaining fuel mass best represented that for the max-q portion of the boost flight.

Results:

The entire ship was hung on springs for the tests. The shakes were completed on schedule. The flutter analysis is in-work.



WHITE KNIGHT FLIGHT TESTS

The following list includes summaries of the flight test activity of the White Knight research aircraft. The White Knight is equipped with the same system components as SpaceShipOne (cabin, ECS, pneumatic, avionics, trim servos, electrical, backup air data, test data, video & TM). Thus, the flight test program of the White Knight includes many tests that focus on SpaceShipOne systems qualification and maturity. Flight crews include program pilots Doug Shane, Mike Melvill, Brian Binnie and Pete Siebold, Cory Bird (White Knight project engineer) and Rick Aldrich (crew chief). This list will be updated monthly.

Flight: 59
Date: 14 Jun 04
Flight Time 1.0 hr
Pilot: Siebold
CoPilot: Melvill

Objectives:
Avionics checkout flight, pilot proficiency and landing practice.

Flight: 58
Date: 14 Jun 04
Flight Time 0.7 hr
Pilot: Melvill
CoPilot: Siebold

Objectives:
Avionics checkout flight, pilot proficiency and landing practice.

Flight: 57
Date: 14 Jun 04
Flight Time: 1.7 hr
Pilot: Binnie
CoPilot: Stinemetze

Objectives:
Flight 15P rehearsal, avionics checkout, pilot proficiency and landing practice.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 55
Date: 06 May 04
Flight Time: 0.4 hr
Pilot: Melvill
CoPilot: Aldrich

Objectives:
Flight 14P rehearsal, avionics checkout, pilot proficiency and landing practice.

Flight: 54
Date: 06 May 04
Flight Time: 1.6 hr
Pilot: Binnie
CoPilot: Stinemetze

Objectives:
Flight 14P rehearsal, avionics checkout, pilot proficiency and landing practice.

Flight: 52
Date: 05 Apr 04
Flight Time: 2.0 hr
Pilot: Siebold
CoPilot: Karkow

Objectives:
Avionics checkout flight, pilot proficiency and landing practice.

Flight: 51
Date: 31 Mar 04
Flight Time: 2.0 hr
Pilot: Binnie
CoPilot: Melvill

Objectives:
SpaceShipOne Flight 13P launch rehearsal, avionics checkout and landing practice.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 50
Date: 30 Mar 04
Flight Time: 2.0 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:

Avionics software evaluation, launch release rehearsal and landing pattern practice.

Flight: 48
Date: 08 Mar 04
Flight Time: 1.4 hr
Pilot: Binnie
CoPilot: Stinemetze

Objectives:

SpaceShipOne flight 12G launch release rehearsal and avionics software evaluation.

Flight: 47
Date: 04 Mar 04
Flight Time: 1.3 hr
Pilot: Binnie
CoPilot: Bird

Objectives:

SpaceShipOne flight 12G launch release rehearsal and avionics software evaluation.

Flight: 46
Date: 18 Feb 04
Flight Time: 0.7 hr
Pilot: Binnie
CoPilot: Melvill

Objectives:

Pilot proficiency, new software build checkout and landing practice.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 45
Date: 18 Feb 04
Flight Time: 1.6 hr
Pilot: Siebold
CoPilot: Binnie

Objectives:
Pilot proficiency, new software build checkout and landing practice.

Flight: 44
Date: 18 Feb 04
Flight Time: 1.7 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:
Pilot proficiency, new software build checkout and landing practice.

Flight: 39
Date: 05 Nov 03
Flight Time: 1.5 hr
Pilot: Siebold
CoPilot: Binnie

Objectives:
Avionics upgrade evaluation and landing pattern practice.

Results:
Satisfactory GPS-aided INS stability and position keeping through a normal launch and glide flight profile.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 36
Date: 22 Sep 03
Flight Time: 1.7 hr
Pilot: Binnie
CoPilot: Stinemetze

Objectives:
Avionics upgrade evaluation.

Results:
Satisfactory GPS-aided INS stability and position keeping through a normal launch and glide flight profile.

Flight: 35
Date: 19 Sep 03
Flight Time: 2.1 hr
Pilot: Siebold
CoPilot: Binnie
FTE: Nichols

Objectives:
SpaceShipOne approach and landing profile review.

Results:
Evaluated a variety of different profiles to assess ease of set-up, forgiveness to off normal starts and pilot situation awareness during the approach.

Flight: 34
Date: 18 Sep 03
Flight Time: 2.7 hr
Pilot: Binnie
CoPilot: Melvill
FTE: Alsbury

Objectives:
SpaceShipOne approach and landing profile review.

Results:
Evaluated a variety of different profiles to assess ease of set-up, forgiveness to off normal starts and pilot SA during the approach.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 33
Date: 11 Sep 03
Flight Time: 2.7 hr
Pilot: Melvill
CoPilot: Binnie
FTE: Tighe

Objectives:

SpaceShipOne approach and landing profile review.

Results:

Evaluated a variety of different profiles to assess ease of set-up, forgiveness to off normal starts and pilot SA during the approach.

Flight: 28
Date: 11 Jul 03
Flight Time: 0.5 hr
Pilot: Siebold
CoPilot: Binnie
FTE: Losey

Objectives:

Pilot proficiency. First flight for SpaceShipOne crew chief.

Results:

Made several practice SpaceShipOne approaches using various configurations and runways. Good exposure for SS1 crewchief Steve Losey on cockpit workload / crew coordination / cabin environment and human factors for Tier-1 mission.

Flight: 27
Date: 11 Jul 03
Flight Time: 0.7 hr
Pilot: Binnie
CoPilot: Siebold
FTE: Stinemetze

Objectives:

Pilot proficiency. First flight for SpaceShipOne lead engineer.

Results:

Made several simulated captive carry low sink rate landings as well as practice SpaceshipOne approaches to various runways. Good exposure for Matt Stinemetze on cockpit workload / crew coordination / cabin environment and human factors for Tier-1 mission



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 26
Date: 11 Jul 03
Flight Time: 2.0 hr
Pilot: Melvill
CoPilot: Binnie
FTE: Rutan

Objectives:

First glide flight profile rehearsal / two ship checklist flow / airspace coordination / Command and Control responsibilities and handoffs. First flight for Burt in the White Knight.

Results:

Exercised all current checklists and SpaceShipOne first flight test cards. Simulated emergencies handled successfully. Good exposure for Burt on cockpit workload / crew coordination / cabin environment and human factors for Tier-1 mission. Flew eleven practice SpaceShipOne approaches from above high key, three with simulated failed avionics and some with other emergencies and runway changes. All were successful.

Flight: 25
Date: 03 Jul 03
Flight Time: 2.2 hr
Pilot: Binnie
CoPilot: Siebold

Objectives:

First glide flight profile rehearsal / two ship checklist flow / airspace coordination / Command and Control responsibilities and handoffs.

Results:

Good exercise of all involved parties and agencies including the Edwards Air Force Base, Joshua Control and Scaled Composites, Utility Mobile ground station.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 23
Date: 02 May 03
Flight Time: 2.3 hr
Pilot: Melvill
CoPilot: Aldrich

Objectives:

Engine performance at altitude. New pilot masks and ECS airflow routing. Regulated bleed air control of the aft cabin temperature (to test the capability to heat SpaceShipOne's nitrous oxidizer. Appraisal of new traffic alert system.

Results:

Engines showed much improved performance up to 50,000 feet. ECS changes confirmed to assure clear windows for landing. Successful bleed air heating test: good control and sufficient energy for SS1 propellant heating.

Flight: 22
Date: 26 Apr 03
Flight Time: 0.3 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:

Airshow for the 'friends and family' unveiling.

Results:

Good show for 1000+ guests. Broadcast media included CNN, ABC, PBS, Tech TV, Discovery & National Geographic TV.

Flight: 21
Date: 18 Apr 03
Flight Time: 0.2 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:

Formal media rollout

Results:

Good show for the VIP/media audience



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 20
Date: 15 Apr 03
Flight Time: 0.7 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:
Repeat airshow maneuver practice

Results:
Minor tweaks to refine the airshow demonstration maneuvers.

Flight: 19
Date: 15 Apr 03
Flight Time: 1.2 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:
Airshow maneuver practice. First flight with Spaceship launch system installed.

Results:
Satisfactory airshow results for various wind conditions. Launch system satisfactory.

Flight: 18
Date: 07 Mar 03
Flight Time: 3.3 hr
Pilot: Melvill
CoPilot: Bird

Objectives:
Revised ECS configuration evaluation. Multiple SFO (simulated flame out) approaches to assess updated flight director steering cues.

Results:
New ECS configuration results encouraging. Engines returned to depot facility for second overhaul repair.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 17
Date: 24 Feb 03
Flight Time: 2.8 hr
Pilot: Binnie
CoPilot: Melvill

Objectives:

Evaluate performance of updated engines. Measure effect of new canted wingtips. Test new landing gear doors and upgraded INS hardware.

Results:

New and different engine irregularities at highest altitudes. Further mods are needed for adequate ECS humidity control. Canted wingtips solved the dihedral effect problem. No flying qualities issues remain.

Flight: 16
Date: 12 Nov 02
Flight Time: 2.0 hr
Pilot: Binnie
CoPilot: Siebold

Objectives:

Continued engine, ECS and avionics evaluation. Simulated wheel brake failure landing rollout.

Results:

Conclusion: aircraft can be landed at MHV if a wheel brake fails. More engine irregularities at high altitude. Engines removed and sent to test cell for fuel control calibration and adjustments.

Flight: 15
Date: 06 Nov 02
Flight Time: 2.4 hr
Pilot: Siebold
CoPilot: Binnie

Objectives:

Continued engine, ECS and avionics evaluation. High-rate nose wheel steering assessment.

Results:

Difficulty maintaining afterburner on left engine near 50,000 feet. Improved ECS configuration showed improved resistance to fogging. Nose wheel steering gearing change about the same.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 14
Date: 24 Oct 02
Flight Time: 0.3 hr
Pilot: Siebold
CoPilot: Shane

Objectives:
FAA-monitored flight for pilot "Type Rating."

Results:
Rating issued

Flight: 13
Date: 24 Oct 02
Flight Time: 0.3 hr
Pilot: Binnie
CoPilot: Siebold

Objectives:
FAA-monitored flight for pilot "Type Rating."

Results:
Rating issued

Flight: 12
Date: 24 Oct 02
Flight Time: 0.3 hr
Pilot: Melvill
CoPilot: Shane

Objectives:
FAA-monitored flight for pilot "Type Rating."

Results:
Rating issued



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 11
Date: 24 Oct 02
Flight Time: 0.3 hr
Pilot: Shane
CoPilot: Melvill

Objectives:
FAA-monitored flight for pilot "Type Rating."

Results:
Rating issued

Flight: 10
Date: 17 Oct 02
Flight Time: 1.1 hr
Pilot: Siebold
CoPilot: Binnie

Objectives:
SpaceShipOne boost profile and steering capture practice. Simulated SS1 glide approaches.

Results:
SS1 simulation good up to at least ~ 70 degree flight path angle.

Flight: 9
Date: 17 Oct 02
Flight Time: 2.2 hr
Pilot: Binnie
CoPilot: Siebold

Objectives:
Boost phase pilot training. Formation flying and air-to-air photography with the Proteus aircraft.

Results:
Adequate visibility and satisfactory flying qualities for formation flying. A photo from this flight later appeared on the cover of Aviation Week (21 Apr 03 issue).



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 8
Date: 16 Oct 02
Flight Time: 1.6 hr
Pilot: Melvill
CoPilot: Binnie

Objectives:

Envelope expansion above 50,000 feet and 0.55M. Avionics software upgrade. Practice SpaceShipOne glide approaches.

Results:

Climbed to 53,000 feet and 0.53M in Military power. Cleared the full required envelope needed for SpaceShipOne launch operations. Flying qualities at highest altitude are satisfactory and will not require dampers. Window fogging not an issue until the cabin was depressurized at 10,000 feet.

Flight: 7
Date: 10 Oct 02
Flight Time: 3.0 hr
Pilot: Shane
CoPilot: Binnie

Objectives:

Completion of Flight 6 objectives. Airspeed and altitude envelope expansion, 45,000 feet / 160 knots / 0.5M

Results:

No structural damping issues found. Engine operation satisfactory. Some window fogging on descent. Some degradation of pneumatic actuators due to cold soaking. Insufficient dihedral effect at high speed/high altitude.

Flight: 6
Date: 09 Oct 02
Flight Time: 0.9 hr
Pilot: Shane **CoPilot:** Binnie

Objectives:

Evaluate rudder mass balance modifications. Effectiveness of engine bleed air heating of the fuselage aft of the cabin (first test of SpaceShipOne Nitrous heating system).

Results:

Rudder vibration problem resolved. Flight cut short due to suspected over-temp of aft cabin bulkhead from engine bleed air.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 5
Date: 06 Sep 02
Flight Time: 2.0 hr
Pilot: Binnie
CoPilot: Shane

Objectives:

New pilot qual eval. Envelope expansion out to 45,000 feet and 160 knots / 0.5M. Practice SpaceShipOne glide approaches. Effectiveness of new tail vortex generators and clipped outboard speed brakes.

Results:

The new VGs eliminated the high-altitude rudder dead-band. Encountered undamped rudder vibration at 25,000 feet and 160 knots during flutter envelope expansion. Engine flameout at 45,000 feet. Un-safe main gear indication for landing (a microswitch adjustment). Clipped otbd speed brake showed no change.

Flight: 4
Date: 27 Aug 02
Flight Time: 2.5 hr
Pilot: Siebold
CoPilot: Shane

Objectives:

New pilot qual eval. Envelope expansion out to 35,000 feet and 150 knots / 0.4M and 3 G's. Engine relight performance. Avionics software upgrade.

Results:

Experienced a rudder dead-band (poor centering) at the higher altitudes. Dihedral effect is neutral at higher speeds. Window fogging on descent. Numerous flight director attitude display resets.

Flight: 3
Date: 19 Aug 02
Flight Time: 2.8 hr
Pilot: Melvill
CoPilot: Shane

Objectives:

New pilot qual eval. Envelope expansion out to 25,000 feet and 150 knots. First flight with the cabin pressurized for environmental control system tests.

Results:

Satisfactory handling and performance. Buffet barriers determined for inboard and outboard speed brakes. Significant window fogging experienced after cold soak at altitude.



TierOne (SpaceShipOne & WhiteKnight) Test Logs

Flight: 2
Date: 05 Aug 02
Flight Time: 1.5 hr
Pilot: Shane
CoPilot: Siebold

Objectives:

First flight test card repeat. Flying qualities assessment and basic performance evaluation. Avionics and pneumatic systems evaluation. Cabin un-pressurized.

Results:

Envelope expansion to 15,000 feet and 140 knots. Overall satisfactory stability, good control harmony and impressive performance. Heavy airframe buffet at high speeds with both sets of speed brakes deployed. "Best airplane the company has ever built."

Flight: 1
Date: 01 Aug 02
Flight Time: 0.2 hr
Pilot: Shane
CoPilot: Siebold

Objectives:

First flight. Handling qualities assessment and basic performance evaluation. Systems evaluation. Cabin un-pressurized.

Results:

Un-commanded hammering auxiliary spoiler deployments after takeoff. Flight aborted to downwind for an uneventful landing. No apparent flying qualities issues noted. Auxiliary spoilers were disabled for future flights.



ROCKET MOTOR GROUND TESTS

The rocket motor main components, the composite nitrous oxidizer tank and CTN (unitized motor case/throat/nozzle) have been in development at Scaled since mid 2001. Those components passed their qualification tests by late 2002. The other motor components (controller, valve, injector, aft bulkhead, head insulation, ignition system and fuel) are being developed and tested by two competing subcontractors. The two companies are eAc and SpaceDev .

Due to the competitive nature of the current rocket ground test program, test details cannot be divulged. The following are the dates of the full-scale motor firing events. This list does not include sub-scale or cold flow tests. All these tests have used full-scale, flight-article components, mounted on our mobile rocket motor test stand. The test stand uses the same tank, CTN and adjacent structure as SpaceShipOne.

VENDOR	DATE OF TEST	INFORMATION
SpaceDev	21 Nov 02	
eAc	16 Jan 03	
eAc	22 Feb 03	
SpaceDev	12 Mar 03	
SpaceDev	19 Mar 03	
eAc	22 Mar 03	
SpaceDev	03 June 03	
eAc	19 June 03	
eAc	24 July 03	full-duration
SpaceDev	31 July 03	full-duration
eAc	4 Sept 03	full-duration
SpaceDev	18 Nov 03	Flight motor qualification run. A ground test to validate the first two planned powered flights of SpaceShipOne. All performance requirements and safety limits were met.

