NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

July 24, 2015

Group Chairman's Factual Report

OPERATIONAL FACTORS

DCA15MA019

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A. ACCIDENT[1]

Operator:	Scaled Composites, LLC
Location:	Koehn Dry Lake, California
Date:	October 31, 2014
Time:	1707 UTC (1007 Pacific Daylight Time)[2]
Vehicle:	Model 339 SpaceShipTwo
Registration Number:	N339SS

B. OPERATIONAL FACTORS GROUP

Captain David Lawrence - Chairman
Operational Factors Division (AS-30)
National Transportation Safety Board (NTSB)
490 L'Enfant Plaza East, SW
Washington, DC 20594-2000

Mr. Mark Stucky[3]
Test Pilot
Scaled Composites
1624 Flight Line Road
Mojave, CA 93501

[1] According to 49 Code of Federal Regulations (CFR) 830.2, the NTSB definition of an "accident" was an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. According to 14 CFR 401.5 Definitions, "Mishap" meant a launch or reentry accident, launch or reentry incident, launch site accident, failure to complete a launch or reentry as planned, or an unplanned event or series of events resulting in a fatality or serious injury (as defined in 49 CFR 830.2), or resulting in greater than $25,000 worth of damage to a payload, a launch or reentry vehicle, a launch or reentry support facility or government property located on the launch or reentry site. For the purposes of this NTSB Operational Factors Group Chairman's Factual Report, the NTSB term "accident" will be used to define this event.

[2] All times listed in this Factual Report will be UTC (Coordinated Universal Time) unless otherwise noted. Times noted as xx:xx:xx are UTC times derived from recorded data.

[3] Mr. Stucky participated as the Scaled Composites party member to the NTSB Operations Group until February, 2015 when he was hired by Virgin Galactic. Mr. Matt Stinemetze, Scaled Composites Tier1B Program Manager, assisted the Operations Group beginning February, 2015.

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Flight Test Pilot
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C. SUMMARY

On October 31, 2014, about 1007 Pacific daylight time, a Scaled Composites SpaceShipTwo (SS2) reusable suborbital rocket,[4] N339SS, experienced an in-flight anomaly during a rocket powered flight test, resulting in loss of control of the vehicle. SS2 broke up into multiple pieces and impacted terrain over a 5-mile area near Koehn Dry Lake, California. One test pilot (the copilot) was fatally injured, and the other test pilot was seriously injured. SS2 had launched from the WhiteKnightTwo (WK2) carrier aircraft,[5] N348MS, about 12 seconds before the loss of control. SS2 was destroyed, and WK2 made an uneventful landing. Scaled Composites was operating SS2 under an experimental permit issued by the Federal Aviation Administration's (FAA) Office of Commercial Space Transportation (AST) under the provisions of 14 Code of Federal Regulations (CFR) Part 437.

D. DETAILS OF THE INVESTIGATION

The Operations Group Chairman launched to Mojave, CA on November 1, 2014. The Operations Group was formed with Party participants from Scaled Composites, Virgin Galactic (VG), and the FAA. The Group made multiple data and document requests, and the pilot operating manuals and guidance from Scaled Composites and Virgin Galactic were requested and received. The FAA certification and medical records were requested for all five crewmembers (three on WK2 and two on SS2). Witness interviews were conducted with FAA and Scaled Composites personnel that were on duty within the control room at the time of the accident.

On November 2, 2014, the Operations Group reviewed Normal and Emergency Procedures for the SS2 and flight test data for the accident flight. Interviews were conducted with Scaled Composites and Virgin Galactic control room engineers and pilots. Additional documentation was requested, and a list of requested data was presented to Virgin Galactic and Scaled Composites.

On November 3, 2014, the Operations Group spent the morning on scene examining wreckage of the main fuselage, cockpit, and rocket motor. The Operations Group returned to Scaled Composites in the afternoon and interviewed control room engineers, including those participants monitoring flight controls, the feather system and telemetry positions. Additional

[4] According to 14 CFR 401.5 Definitions, "suborbital rocket" is defined as a vehicle, rocket-propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which was greater than its lift for the majority of the rocket-powered portion of its ascent.

[5] WK2 was considered the launch vehicle for SS2. According to 14 CFR 401.5 Definitions, "launch vehicle" is defined as a vehicle built to operate in, or place a payload in, outer space or a suborbital rocket.

pilot documentation and mission control (control room) records were requested. FAA database information for the SS2 and WK2 pilots were received and reviewed.

On November 4, 2014, the Operations Group completed interviews with the control room Test Conductor (TC) and the WK2 pilot, accompanied by the Human Performance Group. The Operations Group conducted an interview with a former Scaled Composites Test Conductor, and reviewed ground-based video of the accident sequence. The Operations Group also viewed cockpit and tail boom video of the accident sequence. The Operations Group also conducted a series of test runs in the SS2 simulator at the Scaled Composites facility. Scaled Composites provided additional statements from control room personnel, along with third party weather used during the launch evaluation.

On November 5, 2014, the Operations Group conducted additional Virgin Galactic and Scaled Composites pilot interviews, along with interviews of additional control room engineers. Scaled Composites provided several documents requested on the accident pilots.[6] An additional list of documents and manuals were requested of both Scaled Composites and Virgin Galactic. Group review of the interview summaries began.

On November 6, 2014, the Operations Group worked on field notes. On November 7, 2015, the Operations and Human Performance Group Chairmen traveled to Tehachapi, CA and conducted an interview with the surviving SS2 pilot. Field notes were completed and the field phase of the investigation for the Operations Group was concluded.

From December 8-10, 2014, the Operations Group traveled back to Mojave, California to conduct additional interviews, simulator observations, and the Operations and Human Performance Group Chairmen toured the National Test Pilot School.

On January 13, 2015, the Operations Group Chairman, along with the Systems Safety Group Chairman, met with FAA officials to review FAA documentation related to the Scaled Composites experimental permit and FAA waiver. From January 14-16, 2015, the Operations Group conducted FAA AST interviews in Washington, DC.

From January 27-29, 2015, the Operations Group traveled back to Mojave, CA to conduct additional Scaled Composites and FAA interviews. The Operations Group Chairman also assisted the Human Performance Group Chairman with an interview of the co-pilot's next of kin.

From February 2, 2015 through February 19, 2015, the Operations Group Chairman reviewed acquired documentation from the FAA, including Safety Inspection Plans, and the Operations Group conducted interviews with FAA AST inspectors.

[6] For the purposes of this NTSB Operational Factors Group Chairman's Factual report, "accident pilots" refers to the pilot and co-pilot of the SS2.

E. FACTUAL INFORMATION

1.0 Experimental Permits[7]

On December 23, 2004, President George Bush signed into law the Commercial Space Launch Amendments Act of 2004 (CSLAA). The CSLAA established an experimental permit regime for experimental reusable suborbital rockets.[8] The FAA published experimental permit regulations, 14 CFR part 437, on April 6, 2007.

14 CFR 437.5 Eligibility for an experimental permit, stated:

> *The FAA will issue an experimental permit to a person to launch or reenter a reusable suborbital rocket only for—*
> *(a) Research and development to test new design concepts, new equipment, or new operating techniques;*
> *(b) A showing of compliance with requirements for obtaining a license under this subchapter; or*
> *(c) Crew training before obtaining a license for a launch or reentry using the design of the rocket for which the permit would be issued.*

An experimental permit was an authorization issued by the Federal Aviation Administration (FAA) to allow an experimental reusable suborbital rocket to launch or reenter. A permit was valid for a one-year renewable term and allowed a permittee to conduct an unlimited number of launches and reentries for a particular suborbital rocket design during that time (14 CFR 437.9).

14 CFR 437.7 Scope of an experimental permit, stated:

> *An experimental permit authorizes launch or reentry of a reusable suborbital rocket. The authorization includes pre- and post-flight ground operations as defined in this section.*
> *(a) A pre-flight ground operation includes each operation that—*
> > *(1) Takes place at a U.S. launch site; and*
> > *(2) Meets the following criteria:*
> > > *(i) Is closely proximate in time to flight,*
> > > *(ii) Entails critical steps preparatory to initiating flight,*
> > > *(iii) Is unique to space launch, and*
> > > *(iv) Is inherently so hazardous as to warrant the FAA's regulatory oversight.*
>
> *(b) A post-flight ground operation includes each operation necessary to return the reusable suborbital rocket to a safe condition after it lands or impacts.*

[7] According to 14 CFR 401.5 Definitions, "Experimental Permit" or "permit" meant "an authorization by the FAA to a person to launch or reenter a reusable suborbital rocket."
[8] According to 14 CFR 401.5 Definitions, "Suborbital rocket" was "a vehicle, rocket-propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which was greater than its lift for the majority of the rocket-powered portion of its ascent."

1.1 Scaled Composites Experimental Permit

On May 23, 2012, the FAA's Office of Commercial Space Transportation issued Scaled Composites Experimental Permit No.12–007. The experimental permit was valid for one year, and the FAA renewed the Scaled Composites permit on May 22, 2013 (Rev 1) and May 21, 2014 (Rev 2).[9]

1.2 Scaled Composites Waiver[10]

On March 6, 2013, Scaled Composites submitted an application to renew its experimental permit, which was to expire on May 22, 2013. According to the FAA, in its application for renewal, Scaled Composites included modifications to its permit to reflect changes made to SS2. In a July 18, 2013 Notice of Waiver, the FAA stated that "upon reviewing Scaled's application to renew its permit, the FAA determined that Scaled [Composites] did not fully meet the requirements of 14 CFR 437.29 and 437.55(a)," and the FAA waived Scaled Composites' requirements to comply with those regulations. 14 CFR 437.29 stated:

> *(a) An applicant must perform a hazard analysis that complies with §437.55(a).*
> *(b) An applicant must provide to the FAA all the results of each step of the hazard analysis required by paragraph (a) of this section.*

14 CFR 437.55, Hazard Analysis, part (a) stated, in part:

> *(a) A permittee must identify and characterize each of the hazards and assess the risk to public health and safety and the safety of property resulting from each permitted flight. This hazard analysis must—*
>
> > *(1) Identify and describe hazards, including but not limited to each of those that result from—*
> >
> > > *(i) Component, subsystem, or system failures or faults;*
> > > *(ii) Software errors;*
> > > *(iii) Environmental conditions;*
> > > *(iv) Human errors;*
> > > *(v) Design inadequacies; or*
> > > *(vi) Procedural deficiencies.*

According to the FAA waiver published in the Federal Register (Federal Register / Vol. 78, No. 138) on July 18, 2013, Scaled Composites did not fully comply with 14 CFR 437.55 because "it [Scaled] did not identify human or software error as causing hazards. It did not identify these errors as causing hazards on the grounds that the mitigations it had in place would prevent the hazards from occurring. Scaled emphasizes aircraft and spacecraft design redundancy, flight and maintenance procedures, and ground and flight crew training to mitigate against hazards caused by human and software errors."[11]

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[9] 14 CFR 437.11 Duration of an experimental permit, stated "an experimental permit lasts for one year from the date it was issued. A permittee may apply to renew a permit yearly under part 413 of this subchapter."

[10] For additional information on the Scaled Composites experimental permit and FAA waiver, see System Safety Group Chairman's Factual Report.

[11] Source: Federal Register / Vol. 78, No. 138 / Thursday, July 18, 2013 / Notices.

According to the FAA, Scaled Composites' training program provided part of the basis for the FAA to find that Scaled Composites' permitted activities would not jeopardize public health and safety or safety of property and supported the issuance of the waiver. The FAA said that Scaled Composites' approach to flight safety and training derived from aviation flight testing, and Scaled Composites generally required that its pilots have at least 1,500 hours of flight time, as well as specific experience in jet and glider aircraft. The FAA also said that Scaled Composites used three different devices to train SS2 pilots and crew. The devices were (1) An SS2 simulator, (2) a WK2 aircraft, and (3) an aerobatic aircraft, or other "g" tolerance training device.[12]

In the waiver the FAA stated "Scaled employs a number of different approaches to safety derived from its aviation heritage. These include a training program, an incremental approach to flight testing, use of chase planes, use of a two-pilot model, the remoteness of its operating area, and use of a winged vehicle."

Further, on May 21, 2014 in a letter to Scaled Composites, the FAA "waived specific hazard analysis requirements of 14 CFR 437.29 and 437.55(a) for the second renewal of Experimental Permit No. 12-007. The FAA waived the requirements that Scaled provide a hazard analysis that identifies and verifies and validates mitigation measures for all hazards. The FAA found that a waiver was in the public interest and would not jeopardize public health and safety, safety of property, and national security and foreign policy interests of the United States."

2.0 History of Flight

The accident occurred during the fourth powered flight (PF04) of SS2.[13] The operator of the launch flight was Scaled Composites,[14] and objectives of the test flight included conducting a 38-second burn of a new rocket motor with a (b) (4) system, along with a feathered reentry in excess of 1.00 Mach[15] (1.20 Mach was planned). The maximum Mach speed for the boost portion of the launch was anticipated to be 2.00 Mach.

The flight crews for WK2 and SS2 participated in a "delta" briefing at 1200.[16] The flight was delayed due to low nitrous oxide temperatures that required warming of the nitrous oxide to required limits. According to interviews, the pilots and engineers were also concerned about crosswinds that could exceed the crosswind limitation (10 knots) established for this particular test flight for SS2. The launch window was planned for 1300-1800. The WK2 crew drove in a van to Hanger 78 to pick up the SS2 crew, and then drove to the staging area where WK2 and

[12] Source: Federal Register / Vol. 78, No. 138 / Thursday, July 18, 2013 / Notices.

[13] "Powered flight" referred to an SS2 flight with the rocket motor ignited and providing thrust. "PF04" indicated the fourth powered flight of SS2.

[14] According to 14 CFR 401.5 Definitions, "Operator" meant a holder of a license or permit under 51 U.S.C. Subtitle V, chapter 509.

[15] The Mach number was a ratio between the aircraft's speed and the speed of sound. It was used to indicate how fast one was going when compared to the speed of sound.

[16] According to interviews, the day of flight "delta" brief involved the launch team and SS2/WK2 pilots, and covered items such as weather, NOTAMs, nitrous oxide loading, and a review of the flight test data card.

SS2 were located at about 1430 and began their preflight duties. WK2 (with SS2 mated) departed at 16:19:30.

There were two pilots onboard SS2 for PF04. Both pilots were test pilots employed by Scaled Composites of Mojave, CA. The pilot in the left seat was the pilot flying (PF) and the co-pilot in the right seat was the pilot monitoring (PM). There were two pilots and one Flight Test Engineer (FTE) on WK2. The pilot of WK2 was the Virgin Galactic Chief Pilot.[17] The co-pilot was a Scaled Composites Test Pilot, and the FTE was the SS2 Tier1B Program Manager.[18]

WK2 and SS2 climbed to a pressure altitude of 47,000 feet mean sea level (msl). During climb about 1628, the center SS2 MFD (multi-function display) reset and successfully went through an automatic reboot. Inflight checks of the pressurization system (at 18,000 feet msl) and cabin leak rate (at 30,000 feet msl) were accomplished and were nominal as reported by the crew.[19] Per the 30,000 foot Cabin Leak Check from the M339 SpaceShipTwo Normal Procedures manual (SS2-90P002 REV J), the crew began a "pre-breathe" of 100% oxygen following the 30,000 foot checks.

For PF04, SS2 was powered by a hybrid rocket motor, which used nylon fuel grain and nitrous oxide (N_2O) to generate thrust. According to preliminary cockpit video data, at 17:07:19.27 SS2 was released from WK2, and at 17:07:19.51, the pilot commanded the co-pilot to fire the rocket motor. At 17:07:26.83, the vehicle accelerated through 0.80 Mach, and at 17:07:26.91, the co-pilot made a 0.80 Mach callout. At 17:07:28.39, the co-pilot commented about unlocking the feather system, and at 17:07:28.90, the feather lock handles were moved to the full unlock position. The final frame in the video recording occurred at 17:07:32.80, followed by the vehicle experiencing an inflight breakup.[20] The pilot was thrown from the vehicle during the breakup sequence. During his decent the pilot separated himself from the seat and the parachute subsequently automatically deployed during the descent. The pilot survived with serious injuries. The co-pilot was fatally injured during the accident.[21]

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[17] According to interviews, the Virgin Galactic Chief pilot was operating as a Scaled Composites crew member when he was pilot in command (PIC) of WK2. 14 CFR 401.5 Definitions defined "crew" as any employee or independent contractor of a licensee, transferee, or permittee, or of a contractor or subcontractor of a licensee, transferee, or permittee, who performs activities in the course of that employment or contract directly relating to the launch, reentry, or other operation of or in a launch vehicle or reentry vehicle that carried human beings. A crew consisted of flight crew and any remote operator.

[18] For further information on "Tier1B" see Section 9.0 Scaled Composites, of this Factual Report.

[19] According to 14 CFR 401.5 Definitions, "Nominal" meant, in reference to launch vehicle performance, trajectory, or stage impact point, a launch vehicle flight where all vehicle aerodynamic parameters are as expected, all vehicle internal and external systems perform exactly as planned, and there are no external perturbing influences other than atmospheric drag and gravity.

[20] For additional information, see the Cockpit Video Group Chairman's Factual Report.

[21] For information on the pilot's parachute system, see Survival Factors Group Chairman's Factual Report. For flight crew medical and toxicology information, see Human Performance Group Chairman's Factual Report.

3.0 Flight Crew Information[22]

For powered flight operations, the pilots of SS2 and WK2 were governed under 14 CFR Part 460 – Human Space Flight Requirements, Subpart A – Launch and Reentry with Crew. 14 CFR 460.3 Applicability, stated:

> *(a) This subpart applies to:*
>
> > *(1) An applicant for a license or permit under this chapter who proposes to have flight crew on board a vehicle or proposes to employ a remote operator of a vehicle with a human on board.*
> >
> > *(2) An operator licensed or permitted under this chapter who has flight crew on board a vehicle or who employs a remote operator of a vehicle with a human on board.*
> >
> > *(3) A crew member participating in an activity authorized under this chapter.*
>
> *(b) Each member of the crew must comply with all requirements of the laws of the United States that apply to crew.*

According to the FAA, "during rocket-powered flight tests where WK2 and SS2 were operating as a launch system under an experimental permit, pilot requirements, which included an FAA pilot certificate with an instrument rating, were prescribed by AST in 14 CFR 460.5 Crew Qualifications and Training. Rocket-powered flight under an AST experimental permit included the WK2/SS2 takeoff, WK2/SS2 captive carry, WK2/SS2 air launch, SS2 boost, SS2 apogee, SS2 reentry, SS2 glide and WK2 and SS2 landings."[23] 14 CFR 460.5(c) Crew Qualifications and Training, stated:

> *(c) A pilot and a remote operator must—*
>
> > *(1) Possess and carry an FAA pilot certificate with an instrument rating.*
> >
> > *(2) Possess aeronautical knowledge, experience, and skills necessary to pilot and control the launch or reentry vehicle that will operate in the National Airspace System (NAS). Aeronautical experience may include hours in flight, ratings, and training.*

14 CFR 460.5 (e) Crew Qualifications and Training, stated:

> *(e) Each crew member with a safety-critical role must possess and carry an FAA second-class airman medical certificate issued in accordance with 14 CFR part 67, no more than 12 months prior to the month of launch and reentry.*

According to the Scaled Composites experimental permit, Section 5.1.1 Qualifications, "SpaceShipTwo pilots possessed at least a current 2nd class medical certificate and are certificated commercial pilots with an instrument rating." In addition, the experimental permit stated that Scaled Composites must designate the pilot in command of the SS2 vehicle who was directly responsible for, and had the final authority for, the operation of the vehicle.[24] The pilot in command

[22] Pilot certification information for this Factual Report covers the pilot and co-pilot of SS2. For certification information on the WK2 pilots, see Attachment 23 – WK2 Pilot Information.
[23] See Attachment 25 – FAA Responses.
[24] The flight test data card designated the accident pilot as the pilot in command (PIC).

was authorized to deviate from any requirement of the experimental permit to the extent required to meet an emergency.

In a response to an NTSB inquiry, the FAA stated "during rocket-powered flight tests where WK2 and SS2 were operating as a launch system under an AST experimental permit, *both* WK2 and SS2 pilots were required to comply with the 14 CFR 460.7 Operator Training of Crew."[25] For WK2, compliance with 14 CFR 61.55 was required by its FAA operating limitations. Compliance with 14 CFR 61.58 was not required for the pilots of either vehicle.[26]

Further, the FAA stated "during glide flight tests where WK2 and SS2 were operating as aircraft with individual experimental airworthiness certificates under 14 CFR 91:

- WK2 pilots were required to comply with *both* 14 CFR 61.55 *and* 61.58.
- SS2 pilots were required to comply with *neither* 14 CFR 61.55 *nor* 61.58."[27]

3.1 The SS2 Pilot

At the time of the accident, the accident pilot was 43 years old and resided in Tehachapi, CA. His date of hire with Scaled Composites was December 16, 1996. Previous to his employment with Scaled Composites, he was an aircraft dispatcher and ground instructor in Santa Barbara, CA from October 1991 to December 1994 at Above All Aviation. He was an information services intern at Lockheed Martin Skunk Works in Palmdale, CA from July 1995 to September 1995, and was a flight instructor at the Cal Coast Flying Club in San Luis Obispo, CA from January 1994 to 1996.

He completed a Bachelor of Science Degree in Aerospace Engineering from California Polytechnic State University in 2001.

He had been the Director of Flight Operations for Scaled Composites since 2008, and was a test pilot on the Tier1B program. He reported to the Vice President of Engineering. According to interviews, he had overall responsibility for flight test and normal flight operations, managing flight crews and selecting flight crews, scheduling flight crews, providing training and currency opportunities for flight crews. Prior to assuming the role of Director of Flight Operations he was a test pilot for the SpaceShipOne (SS1) test program, and was responsible for the development of the simulator, avionics/navigation system, and ground control system for the SS1 program. Subsequently, he was the Avionics Project Engineer for the T1B program.

A review of FAA Program Tracking and Reporting Subsystem (PTRS)[28] records found no prior accident, incident or enforcement actions.

[25] See Attachment 25 – FAA Responses.
[26] 14 CFR 61.58 detailed the pilot-in-command (PIC) proficiency check requirements for operation of an aircraft that required more than one pilot flight crewmember or was turbojet-powered. 14 CFR 61.55 detailed qualifications necessary for a second-in-command (SIC).
[27] See Attachment 25 – FAA Responses.
[28] The PTRS is a comprehensive information management and analysis system used in many Flight Standards Service (AFS) job functions. It provides the means for the collection, storage, retrieval, and analysis of data resulting from the many different job functions performed by Aviation Safety Inspectors (ASIs) in the field, the regions, and

3.1.1 The SS2 Pilot's Certification Record[29]

Private Pilot – Airplane Single Engine Land certificate issued May 25, 1991.

Private Pilot – Airplane Single Engine Land Instrument Airplane certificate issued December 18, 1991.

Commercial Pilot – Airplane Single Engine Land Instrument Airplane certificate issued September 27, 1992.

Flight Instructor – Airplane Single Engine certificate issued September 1, 1994.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane certificate issued November 22, 1995.

Flight Instructor – Airplane Single Engine Instrument Airplane certificate issued June 20, 1996.

Flight Instructor – Airplane Single and Multiengine Instrument Airplane certificate issued October 12, 1996.

Renewed: October 30, 1998; October 15, 2000; October 29, 2004; October 27, 2006; October 23, 2008; October 26, 2010; October 29, 2012; October 25, 2014.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane Glider certificate issued May 30, 2003.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane Glider; Authorized Experimental Aircraft: Model 316 SpaceShipOne certificate issued October 1, 2004.[30]

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane Glider; Authorized Experimental Aircraft: Model 316 SpaceShipOne, WhtKnt2 certificate issued October 2, 2013.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane Glider; Authorized Experimental Aircraft: Model 316 SpaceShipOne, Proteus, WhtKnt2 certificate issued January 8, 2014.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane Glider; Authorized Experimental Aircraft: Model 316 SpaceShipOne, Proteus, SpcShp2, WhtKnt2 certificate issued January 17, 2014.

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headquarters. This system provides managers and inspectors with current data on airmen, air agencies, air operators, and many other facets of the air transportation system. Source: FAA.

[29] Source: FAA.

[30] Pilot's Commercial certificate was renewed on February 16, 2009 to add "English Proficient."

3.1.2 The SS2 Pilot's Certificates and Ratings Held at Time of the Accident

Flight Instructor (certificate issued October 25, 2014)
Airplane Single and Multiengine
Instrument Airplane

Commercial Pilot (certificate issued January 17, 2014)
Airplane Single and Multiengine Land
Instrument Airplane Glider
Authorized Experimental Aircraft: Model 316 SpaceShipOne, Proteus, SpaceShipTwo, WhiteKnightTwo

Medical Certificate Second Class (issued August 22, 2014)
Limitations: None

3.1.3 The SS2 Pilot's Flight Times[31]

The accident pilot's flight times:

Total pilot flying time (hours)	2,980
Total Pilot-In-Command (PIC) time	2,550
Total flying time SS2	48.8
Total flying time WK2	188.0
Total flying time last 24 hours*	0.7
Total flying time last 30 days*	2
Total flying time last 90 days	42
Total flying time last 12 months	125

*Includes accident flight while mated to WK2

3.1.4 The SS2 Pilot Experience on SS2 and WK2[32]

The accident pilot was part of the initial cadre of test pilots on the SS2 and WK2 at Scaled Composites. According to Scaled Composites, the accident pilot had flown 60 flights in WK2 as pilot/co-pilot/instructor pilot beginning with the first flight of WK2 on December 21, 2008.[33] He was the pilot of WK2 for 11 glide flights of SS2, beginning on October 28, 2010 (GF02).[34] His

[31] Flight times provided to the NTSB by Scaled Composites were based on written logbooks, electronic logbooks and aircraft records. SS2 times included glide flight, captive carry, and powered flight time. SS2 times included block out for WK2 when mated and landing times for glide flight and powered flight. For SS2 simulator times, see Attachment 14 – SS2 Simulator Logs.
[32] See Attachment 15 – Powered and Glide Flight Assignments
[33] See Attachment 13 – Pilot WK2 Training.
[34] "GF02" indicated the second glide flight of SS2.

last time to pilot WK2 on a SS2 glide flight was August 11, 2012 (GF22), and he conducted a training flight on WK2 on July 22, 2014[35].

He was the pilot of SS2 on 15 previous glide flights, beginning with the first glide flight of SS2 on October 10, 2010 (GF01 – with the accident co-pilot). For two of those 15 glide flights, he served as an instructor pilot (PIC) occupying the right seat of SS2. His last time to pilot SS2 on a glide flight was August 28, 2014 (CF02[36] – again with the accident co-pilot). His last flight on SS2 was a glide flight on October 7, 2014 (GF30) as an instructor pilot (PIC) occupying the right seat. The accident flight (PF04) was the first time the pilot flew SS2 on a powered flight.

The pilot flew glide flights on SpaceShipOne (SS1) on November 14, 2003 and March 11, 2004. He flew the second powered flight of SS1 on April 8, 2004.

3.2 The SS2 Co-Pilot

The accident co-pilot was 39 years old and resided in Tehachapi, CA. His date of hire with Scaled Composites was January 17, 2000. Previous to his employment with Scaled Composites, according to his resume, he was a wing and empennage engineer on the Vantage airplane at Visionaire Jets from January 1998 to January 2000. Prior to that, he worked part time for The Boeing Company during the summers of 1996 and 1997 as a systems engineer and propulsion engineer.

He earned a Bachelor of Science Degree in Aeronautical Engineering from California Polytechnic State University in December 1997.

At the time of the accident, he was a project engineer and test pilot for Scaled Composites. In his test pilot role he reported to the Director of Flight Operations (the accident pilot).

A review of FAA PTRS records found no prior accident, incident or enforcement actions.

3.2.1 The SS2 Co-Pilot's Certification Record[37]

<u>Ground Instructor Advanced</u> certificate issued June 21, 2007.

<u>Private Pilot – Airplane Single Engine Land</u> certificate issued October 6, 1998.

<u>Private Pilot – Airplane Single and Multiengine Land</u> certificate issued July 23, 2000.

<u>Notice of Disapproval – Instrument Airplane (first failure)</u> issued November 8, 2001.
Areas to be reexamined: Areas of Operations I, II, III, VI(c)(d), VII.

[35] See Attachment 13 – Pilot WK2 Training and Attachment 15 – Powered and Glide Flight Assignments.
[36] "CF", or Cold flow flights, were SS2 glide flights that flowed nitrous oxide through the propulsion system without fuel present after release from WK2.
[37] Source: FAA.

Private Pilot – Airplane Single and Multiengine Land Instrument Airplane, Airplane Multiengine Land VFR Only certificate issued April 2, 2002.

Private Pilot – Airplane Single and Multiengine Land Instrument Airplane, Airplane Multiengine Land VFR Only certificate issued April 2, 2002.

Commercial Pilot – Airplane Single Engine Land Instrument Airplane, Private Pilot Privileges Airplane Multiengine Land, Airplane Multiengine VFR Only certificate issued January 9, 2003.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane certificate issued February 4, 2003.[38]

Flight Instructor – Airplane Single Engine certificate issued August 28, 2008.

Flight Instructor – Airplane Single and Multiengine certificate issued June 9, 2010.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane, Glider certificate issued July 16, 2010.

Flight Instructor – Airplane Single Engine and Multiengine Instrument Airplane certificate issued August 30, 2012.
Renewed: June 3, 2014.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane, Glider; Authorized Experimental Aircraft: Proteus certificate issued January 14, 2013.

Commercial Pilot – Airplane Single and Multiengine Land Instrument Airplane, Glider; Authorized Experimental Aircraft: Proteus, Ares certificate issued August 23, 2013.

Airline Transport Pilot – Airplane Multiengine Land; Commercial Pilot Privileges Airplane Single Engine Land, Glider; Authorized Experimental Aircraft: Proteus, Ares certificate issued December 16, 2013.

Airline Transport Pilot – Airplane Multiengine Land; Commercial Pilot Privileges Airplane Single Engine Land and Sea, Glider; Authorized Experimental Aircraft: Proteus, Ares certificate issued December 31, 2013.

3.2.2 The SS2 Co-Pilot's Certificates and Ratings Held at Time of the Accident

Airline Transport Pilot (certificate issued December 31, 2013)
Airplane Multiengine Land;
Commercial Pilot Privileges Airplane Single Engine Land and Sea, Glider
Authorized Experimental Aircraft: Proteus, Ares

[38] The Co-pilot's Commercial certificate was renewed on September 1, 2008 to add "English Proficient."

Flight Instructor (certificate issued June 3, 2014)
Airplane Single Engine and Multiengine
Instrument Airplane.

Medical Certificate Second Class (issued May 22, 2014)
Limitations: Must wear corrective lenses.

3.2.3 The SS2 Co-Pilot's Flight Times[39]

The accident co-pilot's flight times:

Total pilot flying time (hours)	2,154
Total Pilot-In-Command (PIC) time	1,961
Total flying time SS2	31.8
Total flying time WK2	42.8
Total flying time last 24 hours*	0.7
Total flying time last 30 days*	20.7
Total flying time last 90 days	43.4
Total flying time last 12 months	163.9

*Includes accident flight while mated to WK2

3.2.4 The SS2 Co-pilot Experience on SS2 and WK2

The accident co-pilot was part of the initial cadre of test pilots on the SS2 and WK2 at Scaled Composites. According to Scaled Composites, he flew 18 flights in WK2 as co-pilot from the period June 2009 to October 2014.[40] He was the co-pilot of WK2 for 7 glide flights of SS2, beginning on November 17, 2010 (GF03). His last time to co-pilot WK2 on an SS2 glide flight was October 7, 2014 (GF30).

He was the co-pilot of SS2 on 7 previous glide flights, beginning with the first glide flight of SS2 on October 10, 2010 (GF01 - flown with the accident pilot). His last time to co-pilot SS2 on a glide flight was August 28, 2014 (CF02 - again with the accident pilot).

He was the co-pilot on the first powered flight (PF01) for SS2 on April 29, 2013. The accident flight (PF04) was the second time the co-pilot had flown SS2 on a powered flight.

[39] Flight times provided to the NTSB by Scaled Composites were based on written logbooks, electronic logbooks and aircraft records. SS2 times included glide flight, captive carry, and powered flight time. SS2 times included block out for WK2 when mated and landing times for glide flight and powered flight. For SS2 simulator times, see Attachment 14 – SS2 Simulator Logs.
[40] See Attachment 13 – Pilot WK2 Training.

4.0 Vehicle Information

4.1 SpaceShipTwo (SS2)

Photo 1: SpaceShipTwo (Registration N339SS, Serial Number 001).

FAA records indicated SS2, model 339 (Registration N339SS, Serial Number 001) was a glider type vehicle owned by Scaled Composites, LLC. It held an experimental class certificate (Research and Development Category) dated July 23, 2008. Its most recent Special Airworthiness Certificate was issued on October 1, 2014.

According to Scaled Composites literature, the Scaled Model 339 (SS2) was an eight-seat,[41] hybrid-rocket powered, multi-configuration vehicle of composite construction. It had a low-wing, twin-tail booms, outboard horizontal tails, and "extension-only" tricycle landing gear configuration. The vehicle was designed and built by Scaled Composites to provide regular suborbital space access for the general public, and was scheduled to be delivered to Virgin Galactic following completion of flight testing. It was the second stage of a two-stage launch system. The first stage was the Scaled Composites designed and built WK2.

While the SS2 vehicle had an airworthiness certificate in the experimental class and category of research and development, on the accident flight (as an element of a powered flight – PF04), it was being operated as a Commercial Space Transportation Experimental Permitted launch system per Experimental Permit Number EP 12-007. The Experimental Permit was authorized, subject to the provisions of 51 USC Subtitle V, Ch. 509, and the orders, rules, and regulations issued under it to conduct launches.[42]

[41] The prototype was equipped with only two seats for the test crew for this test flight.
[42] See Attachment 20 – SS2 Operating Limitations.

4.2 WhiteKnightTwo (WK2)

Photo 2: WK2 (Registration N348MS, Serial Number 001).

FAA records indicated WK2, Model 348 (Registration N348MS, Serial Number 001) was a fixed wing multi-engine turbine air generator (turbofan-powered) airplane owned by The Spaceship Company (TSC) Vehicle Holdings, Inc. Its most recent airworthiness certificate issuance date was June 30, 2014. Its most recent airworthiness certificate issuance date was June 20, 2014. It had twin fuselages and was flown from the cockpit in the right fuselage. The cockpit configuration in the right fuselage was similar to the cockpit design of the SS2, and enabled WK2 to be used for glide training for SS2 pilots.[43]

While the WK2 vehicle had an airworthiness certificate in the experimental class and category of research and development, on the accident flight (as an element of a powered flight – PF04) it was being operated as a Commercial Space Transportation Experimental Permitted launch system per Experimental Permit Number EP 12-007. The Experimental Permit was authorized, subject to the provisions of 51 USC Subtitle V, Ch. 509, and the orders, rules, and regulations issued under it to conduct launches.

4.3 Chase Planes

Scaled Composites used an Extra EA300/L (Registration N24GA) single-engine acrobatic airplane as a chase plane for the launch of SS2 on PF04, and planned to use WK2 as an additional chase plane during SS2 re-entry as a glider. According to FAA records, the Extra EA300/L used for PF04 was owned by 5G Aviation Inc. in Santa Ana, CA.[44] It was operated by Virgin Galactic, and for PF04 was piloted by a Virgin Galactic test pilot with a photographer on board.

In the waiver issued by the FAA on July 18, 2013 the FAA referenced Scaled Composites use of chase planes as follows:

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[43] For further information on WK2 training, see Section 11.4 WK2 Training of this Factual Report.
[44] Source: http://registry.faa.gov/aircraftinquiry/NNum_Results.aspx?NNumbertxt=24GA.

Scaled uses two chase planes and two pilots for SS2's flight. Scaled's use of two chase planes and two pilots allows Scaled to identify problems when the system itself fails to disclose them, and provides redundancy. The chase planes are able to monitor the WhiteKnightTwo and the SS2, so that if there is a computer failure and the pilot would not otherwise know of an external failure, such as the failure of the landing gear to lower, the chase planes are able to provide that information. Upon reentry of SS2, Scaled uses WhiteKnightTwo as an additional chase plane.

The chase planes provide additional situational awareness for pilots and crew on the carrier aircraft and SS2, and ground crew. The use of two chase planes is a safety measure that eliminates or mitigates potential hazards. The chase planes are able to identify anomalies and communicate them directly to the SS2 or carrier airplane pilots. They serve as an extra set of eyes to ensure that any unplanned events that do occur are identified and addressed as quickly as possible.

The Scaled Composites experimental permit application did not have a reference to the use of chase planes. The Scaled Composites Flight Test Project Engineer for the SS2 flight tests stated in an interview he reviewed their original experimental permit application to see if there was language that discussed the use of chase airplanes, and he could not find any representation about chase airplanes in the Scaled Composites experimental permit. In the context of the waiver, he said the FAA never asked Scaled Composites if they were using two chase airplanes for powered flight operations.

5.0 Flight Operating Rules for PF04

Launch operations were governed under 14 CFR 437. Scaled Composites launch and flight operations were also required to comply with the applicable provisions of 14 CFR Part 91 that were specified in the Scaled Composites experimental permit to ensure public safety. 14 CFR 437.71 Flight Rules, stated:

(a) Before initiating rocket-powered flight, a permittee must confirm that all systems and operations necessary to ensure that safety measures derived from §§437.55, 437.57, 437.59, 437.61, 437.63, 437.65, 437.67, and 437.69 are within acceptable limits.
(b) During all phases of flight, a permittee must—
(1) Follow flight rules that ensure compliance with §§437.55, 437.57, 437.59, and 437.61; and
(2) Abort the flight if it would endanger the public.
(c) A permittee may not operate a reusable suborbital rocket in a careless or reckless manner that would endanger any member of the public during any phase of flight.
(d) A permittee may not operate a reusable suborbital rocket in areas designated in a Notice to Airmen under §91.137, §91.138, §91.141, or §91.145 of this title, unless authorized by:
(1) Air Traffic Control; or
(2) A Flight Standards Certificate of Waiver or Authorization.

(e) For any phase of flight where a permittee operates a reusable suborbital rocket like an aircraft in the National Airspace System, a permittee must comply with the provisions of part 91 of this title specified in an experimental permit issued under this part.

During rocket-powered flight tests where WK2 and SS2 were operated as a launch system under an experimental permit, operational requirements were as prescribed by AST in Scaled Composites' Experimental Permit (AST EP-12-007A, Terms and Condition #8), which stated:

Compliance with Aviation Requirements:
During launch operations WK2 must hold a valid experimental airworthiness certificate and must operate in accordance with the operating limitations of that certificate and the applicable sections of 14 CFR 91.[45]

According to the FAA, "although the AST experimental permit requires a valid experimental airworthiness certificate, the experimental airworthiness certificates are held in abeyance during the rocket-powered flight tests (AVS [Aviation Safety] does not exercise compliance monitoring during AST activity)."[46]

During glide flight tests, WK2 and SS2 operated as aircraft with individual experimental airworthiness certificates under 14 CFR 91 General Operating and Flight Rules.[47]

6.0 Weight and Balance

Weight and balance data was provided on the PF04 flight test card (Revision U). Maximum weights were listed in each vehicle's Pilot Operating Handbook (POH). All weights are listed in pounds (lbs).

6.1 SpaceShipTwo (SS2)

SS2 PF04 Consumable weights		Landing	
	Pre-Dump	**Abort**	**Normal**
FPT (forward pressure tank)[48]	(b) (4)		
Main Oxidizer Tank (MOT)			
(b) (4)			

[45] Source: FAA.
[46] See Attachment 25 – FAA Responses. Aviation Safety (AVS) is an organization within the FAA responsible for the certification, production approval, and continued airworthiness of aircraft; and certification of pilots, mechanics, and others in safety-related positions. Source: http://www.faa.gov/about/office_org/headquarters_offices/avs/.
[47] Source: FAA.
[48] (b) (4) Source: The SS2 POH (SS2-90P001 REV D – 3 dated September 2013) page 128, and Scaled Composites.

CTN[49]	(b) (4) [redacted]		
Totals			

SS2 PF04 Weights (maximum weights in **bold**)		
	Nominal Landing Weight (C.G. 360.3)[51]	(b) (4) [redacted]
	SS2 Consumables (planned fuel burn, N_2O and Helium)	
	SS2 Release Weight (C.G. 366.3)	
	SS2 Dumpable weights (full – residuals)	
	SS2 Abort Landing Weight	
	Full Burn Landing Weight	
	Abort Landing Weight	
	Maximum Abort Landing Weight	

6.2 WhiteKnightTwo (WK2)

WEIGHT & BALANCE / PERFORMANCE (maximum weights in **bold**)		
	Basic Operating Weight	(b) (4) [redacted]
	Pilot Weights (Pilot and Co-pilot and FTE)	
	Zero Fuel Weight	
	Maximum Zero Fuel Weight	
	Fuel Weight (takeoff)	
	Ramp Weight	
	SS2 weight	
	Maximum Taxi Weight	
	Taxi Fuel Burn (estimated)	
	Actual Takeoff Weight	
	Maximum Takeoff Weight (with SS2)	
	Estimated Fuel Burn	
	Estimated Landing Weight (unmated)	
	Maximum Landing Weight (mated/unmated)	

7.0 Meteorological Information[53]

Weather reported near the time of the accident (1707) was:

[49] According to the SS2 POH (SS2-90P001 REV D – 3 dated September 2013), page 127, the Case/Throat/Nozzle Assembly (CTN) included the combustion chamber that contained the solid fuel grain for the rocket motor.

[50] [redacted] (b) (4)

[51] According to the SS2 POH (SS2-90P001 REV D – 3 dated September 2013), the aft limit CG for launch [redacted] (b) (4) and the forward limit CG for burn out [redacted] (b) (4)

[52] [redacted] (b) (4) Source: Virgin Galactic.

[53] For more detailed weather information, see Meteorology Group Chairman's Factual Report.

SA 31/10/2014 17:15-> METAR KMHV 311715Z AUTO 20011KT 10SM CLR 20/04 A2996 RMK AO1=

8.0 Airport/Airspace Information

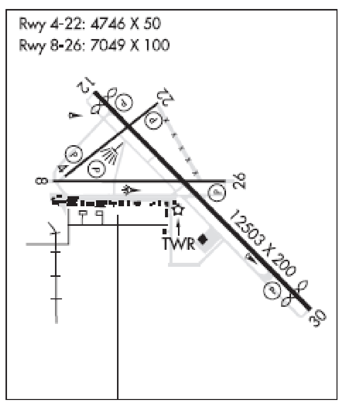
8.1 KMHV Airport[54] (Mojave Air and Space Port)

WK2 with SS2 departed from Mojave Airport for PF04. Mojave Airport (KMHV) was located one mile east of Mojave, CA at an elevation of 2,801.4 feet above mean sea level (msl). KMHV occupied about 3,300 acres, and was located about 70 miles North- Northeast of Los Angeles, CA.

The main runway used by WK2 during mated and unmated operations at KMHV was runway 12/30. Runway 12/30 was 12,503 long and 200 feet wide with an asphalt surface in excellent condition. Runway 08/26 was an alternate runway that could support Scaled Composites operations, and was 7,050 feet long and 100 feet wide.

CALIFORNIA 151

MOJAVE (MHV)(KMHV) 1 E UTC–8(–7DT) N35°03.54´ W118°09.04´ **LOS ANGELES**
2801 B S4 **FUEL** 100LL, JET A TPA—See Remarks NOTAM FILE MHV **H–4I, L–3D, 7–C**
RWY 12–30: H12503X200 (ASPH) S–120, D–150, 2D–450 HIRL **IAP, AD**
RWY 12: REIL. PAPI(P4L)—GA 3.0° TCH 68´. Thld dsplcd 600´. 1.0% down.
RWY 30: REIL. PAPI(P4L)—GA 3.0° TCH 62´. Thld dsplcd 900´. Rgt tfc. 1.0% up.
RWY 08–26: H7049X100 (ASPH) S–40, D–60, 2D–88 MIRL
0.6% up W
RWY 08: PAPI(P2L)—GA 4.0° TCH 55´.
RWY 26: PAPI(P2L)—GA 3.0° TCH 52´. Rgt tfc.
RWY 04–22: H4746X50 (ASPH) S–40, D–60, 2D–60 MIRL
RWY 04: PAPI(P2L)—GA 4.0° TCH 39´. Pole.
RWY 22: PAPI(P2L)—GA 3.0° TCH 40´. Rgt tfc.



AIRPORT REMARKS: Attended continuously. Fuel avbl 1530–0030Z‡ other times ctc security on CTAF, fee charged. Be alert to high speed activity invof arpt. Fee charged. Paving width Rwy 08 200´. TPA–. CAT C/D and all turbojet acft TPA 4301´ MSL (1500´ AGL). CAT A/B acft TPA 3801´ MSL (1000´AGL). Helicopter TPA 3301´ MSL (500´ AGL) and use south entry and departure. Unlgtd twys connect rwy ends 08 and 12 and Rwy 22 and Rwy 26. Rwy 04–22 cracking, loose gvl and uneven sections. Due to rapidly rising terrain west and northwest of the arpt CAT/C/D and all turbojet acft ldg Rwy 08 must remain at or above 4301´ MSL until commencing base leg turn and at or above 3800´ MSL until established on A 2.25 NM final. Rwy 12 unusable byd 2.5 NM. ACTIVATE MIRL Rwy 08–26, Rwy 04–22 and HIRL Rwy 12–30, REIL Rwy 12 and Rwy 30—CTAF.
AIRPORT MANAGER: 661-824-2433
WEATHER DATA SOURCES: AWOS–3 132.225 (661) 824–5218. SAWRS.
COMMUNICATIONS: CTAF 127.6
JOSHUA APP/DEP CON 133.65
TOWER 127.6 (1500–0100Z‡ Mon–Fri) **GND CON** 123.9

NOT FOR NAVIGATION

AIRSPACE: CLASS D svc 1500–0100Z‡ Mon–Fri other times CLASS G.
RADIO AIDS TO NAVIGATION: NOTAM FILE EDW.
EDWARDS (L) VORTAC 116.4 EDW Chan 111 N34°58.94´ W117°43.96´ 268° 21.1 NM to fld. 2378/15E.
TACAN AND DME unusable
095°–115° byd 15 NM blo 2,600´

Figure 1: KMHV Airport Facility Directory Information (source: FAA)

[54] Source: http://www.airnav.com/airport/KMHV.

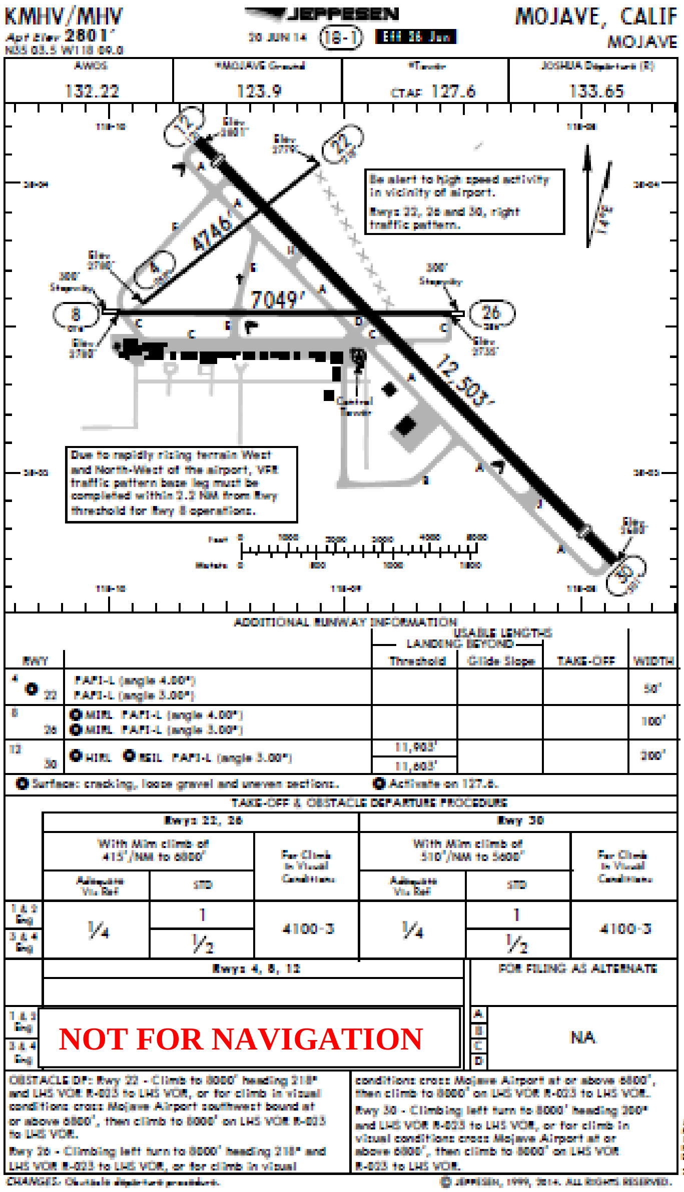


Figure 2: Jeppesen KMHV 18-1 Airport Chart.

According to the Scaled Composites experimental permit (Revision 2, dated May 23, 2014), the ATC (Air Traffic Control) tower at the Mojave Air and Space Port (KMHV) must be in operation, and Class D airspace in effect during launch. [55] According to the KMHV Airport Facility Directory (see Figure 1), Class D services were available from 1500Z to 0100Z (accident occurred at 1707Z). According to Scaled Composites, by agreement with the Mojave Air and Space Port, the class D services commenced on the day of the test flight at 1000Z.

[55] The Aeronautical Information Manual (AIM), Section 3-2-5 Class D Airspace, stated that Class D airspace was generally that airspace from the surface to 2,500 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower.

8.1.1 Mojave Air and Space Port Launch Site

On June 17, 2004, the FAA's Office of Commercial Space Transportation (FAA/AST) orginally issued the Mojave Air and Space Port (KMHV) authorization to operate certain portions of the airport as a launch site (License Number LSO 04-009). The license was renewed on June 13, 2014 (Revision 1, effective June 17, 2014). According to the license:

> *Mojave Air and Space Port is authorized to operate a launch site:*
>
> > *(a) consisting of runways 8-26 and 12-30, and an area with a 1250 foot radius centered at 35° 04' 21.44" North latitude and 118° 09' 19.44" West longitude.*
> > *(b) to support suborbital reusable launch vehicle missions authorized by an FAA license or permit to take-off at Mojave Air & Space Port.*[56]

In 2012, the FAA evaluated the potential environmental impacts of issuing experimental permits and/or launch licenses to operate SpaceShipTwo reusable suborbital rockets and WhiteKnightTwo carrier aircraft at the Mojave Air and Space Port in Mojave, California, and on June 30, 2012 the FAA determined that preparation of an Environmental Impact Statement was not required, and the FAA issued a FONSI (finding of no significant impact). According to the FAA:

> *After reviewing and analyzing currently available data and information on existing conditions and the potential impacts of the Proposed Action, the FAA has determined that issuing experimental permits and/or launch licenses to operate SpaceShipTwo and WhiteKnightTwo at the Mojave Air and Space Port would not significantly impact the quality of the human environment.*[57]

8.2 R-2508 Airspace

14 CFR 437.25, Flight Test Plan, stated in part:

> *An applicant must—*
> *(b) Identify and describe the geographic coordinates of the boundaries of one or more proposed operating areas where it plans to perform its flights and that satisfy § 437.57(b) of subpart C. The FAA may designate one or more exclusion areas in accordance with § 437.57(c) of subpart C.*

For PF04, Scaled Composites operated under a written agreement with the R-2508 Complex Control Board (CCB), and the US Air Force Flight Test Center (AFFTC). SS2 flight operations were planned to remain within the R-2508 airspace. The R-2508 Complex was composed of internal restricted areas; Military Operations Areas (MOAs), Air Traffic Control Assigned Airspace (ATCAAs), and other special airspace. A letter of agreement between Scaled Composites and the R-2508 CCB regarding use of R-2508 required two-way radio communications and an operating transponder. The SS2 transponder provided real-time position

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[56] See Attachment 16 – Airport and Airspace Information.
[57] See Attachment 22 - FAA Mojave Airport Environmental Assessment.

and velocity to ATC during aircraft operations (i.e., boost through landing phases of flight) and SS2 maintained two-way radio communication with ATC from take-off to landing. SS2 also transmitted telemetry data to the Scaled Composites Ground Station, which maintained two-way communication with ATC from take-off to landing. Scaled Composites also agreed to provide the R-2508 Central Coordinating Facility (CCF) with a five-day notification preceding each operation or group of operations.

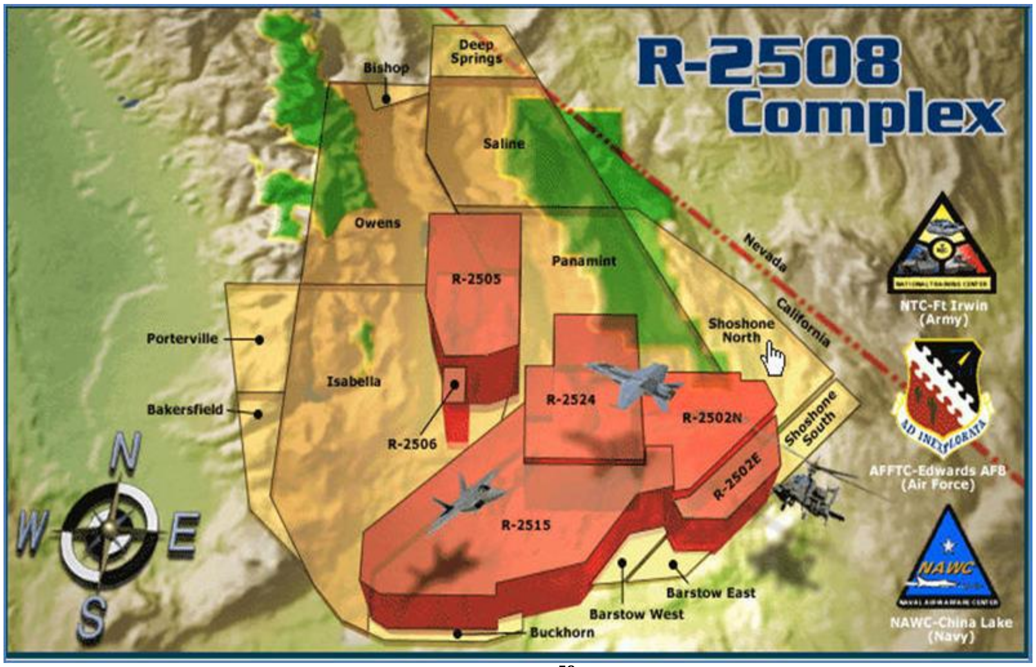

Figure 3: Overview of R-2508 Complex Airspace[58]

High Desert Combined Control Facility (E10 - call sign "Joshua Approach") was the FAA Air Traffic Control Facility that provided traffic & boundary advisories and mission support services within R-2508 Complex shared use airspace. According to the R-2508 Central Coordinating Facility Users Handbook (Section 3.2 Traffic & Boundary Advisories and ATC Services, page 3-2), TRACON[59] did not provide separation services to aircraft operating within the R-2508 Complex; operations in Complex airspace were on a "see-and-avoid" basis.

14 CFR 437.31 Verification of operating area containment and key flight-safety event limitations, stated:

> *(a) An applicant must identify, describe, and provide verification evidence of the methods and systems used to meet the requirement of §437.57(a) to contain its reusable suborbital rocket's instantaneous impact point within an operating area and outside any exclusion area. The description must include, at a minimum—*
> *(1) Proof of physical limits on the ability of the reusable suborbital rocket to leave the operating area; or*

[58] Source: R-2508 Central Coordinating Facility Users Handbook (29 April 2014).
[59] Terminal Radar Approach Control Facilities.

(2) Abort procedures and other safety measures derived from a system safety engineering process.
(b) An applicant must identify, describe, and provide verification evidence of the methods and systems used to meet the requirements of §437.59 to conduct any key flight-safety event so that the reusable suborbital rocket's instantaneous impact point, including its expected dispersions, is over unpopulated or sparsely populated areas, and to conduct each reusable suborbital rocket flight so that the reentry impact point does not loiter over a populated area.

(b) (4)

[redacted]

9.0 Scaled Composites

Scaled Composites, LLC, was a Delaware Corporation and a wholly owned subsidiary of Northrop Grumman Corporation. The SS2 research and development program was called "Tier1B" internally. The goals for the Tier1B program were to test and evaluate the vehicle and the systems and to improve safety and reliability of manned commercial space flight. SS2 was designed to be taken to a launch altitude of approximately 50,000 feet by its carrier aircraft WK2, and after reaching an approximate apogee of 360,000 feet, SS2 would glide back and land horizontally.[61]

Scaled Composites developed two vehicles for the Tier 1B program in order to meet the goals of its contract with Virgin Galactic: WK2 and SS2.

WK2 had been in flight test since December 2008 and SS2 since March 2010. The Spaceship Company (TSC) took ownership of WK2 on February 11, 2014.[62]

9.1 Organizational Structure

The Scaled Composites organizational structure included departments of Engineering, Operations, Programs/Business Management, Shared Services, and Finance.[63] Scaled Composites

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[60] According to 14 CFR 401.5 Definitions, "Instantaneous impact" point was defined as an impact point, following thrust termination of a launch vehicle, calculated in the absence of atmospheric drag effects.
[61] Source: Scaled Composites Experimental Permit No.12–007.
[62] In October 2012, Virgin Galactic announced that it had acquired full ownership of The Spaceship Company.
[63] See Attachment 19 – Scaled Organizational Charts.

was a proof-of-concept and prototyping aerospace company tasked with developing a reliable, reusable, and affordable suborbital manned commercial space launch system prototype for Virgin Galactic.

Test pilots at Scaled Composites were organized under the Engineering Department and reported to the Director of Flight Operations. The Director of Flight Operations was a direct report to the Vice President of Engineering. At the time of the accident, there were four designated Scaled test pilots participating in the SS2 test program.

According to interviews with Scaled Composites employees, test pilots also served as design engineers, flight test engineers, or project engineers on other Scaled Composites programs not related to the Tier1B program, and would have an additional manager to report to. According to the Director of Flight Operations, the pilots working on projects not related to SS2 reported up through the VP of Engineering and not necessarily directly to him.[64]

Test pilots for SS2 provided technical support for aircraft and payload system development flight operations, prepared flight test plans, cards, pilot operating handbook revisions and participated in pre/post flight briefings. They flew test flights as pilot or co-pilot, supported ground tests and documented test results.[65]

According to the Director of Flight Operations, as a test pilot within the company, one of the important aspects was that they participated as a team member early in the program so they could gain insight to participate as a test pilot later in the program. That was how they ensured the pilots and FTEs were ready to participate later in the program. It did not always happen like that, but that was what they strived for.[66]

According to the Scaled Composites Vice President of Engineering, the organizational structure placed the pilots within engineering rather than operations because of historical precedent and also because their test crew was sourced out and developed out of engineering. A Scaled Composites test pilot's workload was split between multiple projects. The percentage of time split between projects was based on what was appropriate to meet the project requirements to be safe, balancing all of the priorities, and varied on a case by case basis. For the accident co-pilot, the Director of Flight Operations estimated that about 90% of the accident co-pilot's workload involved responsibilities not related to SS2. The Director of Flight Operations (accident pilot) estimated his own workload as 80% covering responsibilities other than the SS2 program.[67]

Scaled Composites' President was the Safety Official for the organization. An individual on a specific program would be assigned as the Safety Officer for the program, who typically was the Project Engineer, Program Manager or the lead engineer. According to the Vice President of Engineering, that safety official would balance cost, schedule, technical and safety issues for the program. Per their process, if there was a test coming up, the program safety official would ask if it was a major test that required a readiness review. Senior management would be informed

[64] See Attachment 1 – Interview Summaries.
[65] See Attachment 21 – Scaled Test Pilot Assignment Description.
[66] See Attachment 1 – Interview Summaries.
[67] See Attachment 1 – Interview Summaries.

and could call for a readiness review as well. At this point, the company safety official would come back into the process, and then they would have the review.[68] The President of Scaled Composites delegated the company safety official role to the Scaled Composites Vice President/General Manager.

9.2 Scaled Flight Test Program[69]

According to the Scaled Composites experimental permit, the SS2 Tier1B flight test program followed an incremental approach to gradual envelope expansion. The test program for SS2 was modeled from the SpaceShipOne (SS1) program. The test program was divided into 3 phases:

Phase I: Subsonic Flights
Phase II: Powered Flight to Maximum Altitude
Phase III: Repeatability Demonstrations

The following key individuals were named within the company's typical flight test organizational structure:

- Test Director
- Project Engineer
- Project Pilot
- Flight Test Engineer
- Crew Chief

According to a presentation provided to the NTSB by Scaled Composites, the roles and responsibilities were defined as follows:

The Test Director at Scaled Composites had the following roles:
- Provided an environment to the test team where everyone had equal responsibility for the safe and efficient conduct of a test
- Conducted informal reviews of test plans, reviews and approved flight test cards
- Represented the company's interests

The Project Engineer (PE) at Scaled Composites had the following roles:
- Supported the test program by representing the design and capabilities of the vehicle
- Responsible for vehicle configuration
- Led remaining design team and/or team members working in that capacity

The Project Pilot had the following roles:
- Represented the operational side of the house
- Supported the Project Engineer and design team in development of the aircraft operating procedures and documentation
- Provided input to the FTE in test planning and risk mitigation

[68] See Attachment 1 – Interview Summaries.
[69] Sources: Scaled experimental permit and presentations/documentation provided to the NTSB.

- Represented test pilots supporting the program including recommendations on design changes, operational limitations, etc.
- Typically responsible for flight to flight crew selection with input from the lead FTE and Test Director

The Flight Test Engineer had the following roles:
- Responsible for test planning, test documentation and data analysis
- A key member of the aircrew on multi-seat vehicles
- Worked closely with the PE to define instrumentation requirements
- Ultimately his job was to plan tests, support the execution of the test and provide PE feedback on the vehicles ability to meet the program requirements

The Crew Chief had the following roles:
- Performed aircraft maintenance
- Responsible for quality and configuration control
- Implemented design changes with definition from design team project engineers
- Provided valuable feedback to design team on design and fabrication
- Performed required inspections and represented the aircraft's airworthiness to the FAA
- Led ground support and fabrication team

For the T1B program the following flight test roles were used:
- Test Director
- Program Manager[70]
- Project Engineers
- Project Pilot
- Project Flight Test Engineer
- Crew Chief

9.3 Flight Test Reviews

According to Scaled Composites, following PF03 on January 10, 2014, the Tier1B program conducted a series of reviews leading up to PF04 (October 31, 2014) based on the progress of the program. The following timeline was provided to the NTSB:

- GF029 Test Readiness Review (FRR) occurred July 17, 2014
- Qualification Hot Firing One (Q1) Test Readiness Review (TRR) occurred September 18, 2014
- Q2 TRR occurred September 30, 2014
- CF02 FRR occurred August 12, 2014
- PF04 FRR occurred October 3, 2014
  - *GF030 occurred October 7, 2014*
- Q3 TRR occurred October 8, 2014

[70] Due to the scale of T1B program a Program Manager (PM) position was used to provide overall direction and management for the program.

- T1b Town Hall Meeting occurred October 22, 2014
    - *PF04 Data systems preflight occurred October 23, 2014*
- PF04 Delta FRR occurred October 27, 2014
    - *PF04 Card Review occurred October 28, 2014 (AM)*
    - *PF04 Airport/FAA/First Responders Operations Briefing occurred October 28, 2014 (PM)*
    - *PF04 Ground Operations Brief occurred on October 28, 2014 (PM)*
- PF04 Executive FRR occurred October 29, 2014
    - *PF04 Card Brief , Maintenance and ER Brief occurred October 30, 2014 (AM)*
    - *PF04 Comm Checks occurred on October 30, 2014 (PM)*
    - *PF04 Mission Brief occurred October 31, 2014 (AM)*

For a detailed description of the testing and reviews conducted prior to PF04, see Attachment 24 – Flight and Test Reviews, of this Factual Report.

10.0 SS2 Onboard Materials

During the flight, the SS2 pilots had the following guidance material available to them in the cockpit:

- SpaceShipTwo (SS2) Pilot Operating Handbook
- M339 SpaceShipTwo Normal Procedures
- M339 SpaceShipTwo Emergency Procedures
- PF04 flight test data card
- Navaero Tpad tablet

10.1 SS2 Pilot Operating Handbook (POH)

The SpaceShipTwo (SS2) Pilot Operating Handbook (SS2-90P001, Revision D, dated September 3, 2013) documented the configuration, systems, operating limitations, procedures and performance of the SS2 suborbital space plane. The scope of the SS2 Pilot Operating Handbook (POH) included design philosophy and lessons learned as appropriate to document the design and development of the vehicle.

There were two supplements to the SS2 POH. SS2-90BP001 (POH Rev D-Interim Safety Supplement reflected the installation of new Instrument Panels (IP), a new window heater system for the pilot's window (left side only) and the addition of a (b) (4) system. SS2-90BP001 (POH Rev D - Interim Safety Supplement 2) reflected the installation of a new Environmental Control System panel (IP6B).

According to interviews with AST inspectors, the POH was reviewed during the application evaluation process, but was not an FAA-approved document.

10.2 Normal Procedures (NPs)

Normal SS2 procedures were defined in the M339 SpaceshipTwo Normal Procedures (SS2-90P002, Revision J, Change 5, dated 14 October 2014), and included nominal pre-flight, flight and post-flight procedures. Specific pilot procedures used during the boost phase for PF04 were included on the PF04 flight test data card.[71]

10.3 Emergency Procedures (EPs)

Emergency SS2 procedures were defined in the M339 SpaceshipTwo Emergency Procedures (SS2-90P003, Revision L, Change 2, date 14 October 2014).

10.4 Flight Test Data Card

Mission specific information for PF04 was included on the PF04 flight test data card (Revision U), and carried by the pilots for SS2 flights. This card included vehicle restrictions and limitations, weight and balance information, performance information, mission timeline information, and expected pilot actions during the various phases of flight. The card also included expected pilot callouts during the boost phase of flight.[72]

10.5 Navaero Tpad

The pilots of SS2 had a Navaero Tpad (tactical pad) tablet that provided a means of displaying data that was recorded by the DAS (Data Acquisition System), and provided the pilots additional data and information that was not necessarily displayed on the MFD. The Tpad was configurable based on the test specifications of each individual flight.

11.0 SS2 Training

Scaled Composites and Virgin Galactic test pilots trained together in preparation for glide and powered flights of the SS2 and WK2. Required training for SS2 pilots for powered flight operations was defined in 14 CFR 460.5 Crew Qualifications and Training. The regulation stated in part:

> *(a) Each crew member must—*
>
> > *(1) Complete training on how to carry out his or her role on board or on the ground so that the vehicle will not harm the public; and*
> >
> > *(2) Train for his or her role in nominal and non-nominal conditions. The conditions must include—*
> >
> > > *(i) Abort scenarios; and*
> > >
> > > *(ii) Emergency operations.*

The regulation further stated:

[71] See Section 13.1.1 SS2 PF04 Pilot Tasks of this Factual Report.

[72] For additional information on flight test data cards for powered flights, see Section 10.4 Flight Test Data Card of this Factual Report.

(c) A pilot and a remote operator must—

(1) Possess and carry an FAA pilot certificate with an instrument rating.

(2) Possess aeronautical knowledge, experience, and skills necessary to pilot and control the launch or reentry vehicle that will operate in the National Airspace System (NAS). Aeronautical experience may include hours in flight, ratings, and training.

(3) Receive vehicle and mission-specific training for each phase of flight by using one or more of the following—

(i) A method or device that simulates the flight;

(ii) An aircraft whose characteristics are similar to the vehicle or that has similar phases of flight to the vehicle;

(iii) Flight testing; or

(iv) An equivalent method of training approved by the FAA through the license or permit process.

(4) Train in procedures that direct the vehicle away from the public in the event the flight crew abandons the vehicle during flight; and

(5) Train for each mode of control or propulsion, including any transition between modes, such that the pilot or remote operator is able to control the vehicle.

According to the Scaled Composites experimental permit application, Section 5.1.2 Training, Scaled Composites used a "three-prong approach" to train SS2 pilots, which included the SS2 simulator, the WK2 aircraft, and an aerobatic Extra EA300/L aircraft.

According to the Scaled Composites experimental permit application, Section 5.1.3 Training Records, the Scaled Composites Director of Flight Operations kept a written training record for all Scaled Composites pilots. The training records for each pilot included, but were not limited to, the following items:

- *Aircraft and system checkouts completed*
- *License, rating, and Medical certification status*
- *Training received*
- *Current and expired Letters of Authorization (LOAs)*

According to the Scaled Composites Director of Flight Operations, for "AST regulated flights" (SS2 powered flights), Scaled Composites had an internal requirement for a minimum of three combined group simulator sessions for each powered flight, presuming that the crew had participated in previous flights.

For the Extra EA300/L training, SS2 pilots conducted a minimum of three training flights in preparation for a powered flight, including gaining and maintaining "g" tolerance and upset recovery training.

According to the Scaled Composites experimental permit application, Section 5.1.2.2 WK2, Scaled Composites pilots would fly at least three WK2 simulated approaches for proficiency prior to a SS2 launch. According to the Director of Flight Operations, WK2 was able to simulate the SS2 approach and landing phase, but not other phases.

According to Scaled Composites, there were no grade sheets completed for either WK2 or Extra flights in preparation for PF04. The flight objectives and tasks performed were documented on test cards for the flights.

11.1 Ground Training

According to a review of Scaled Composites pilot training records provided to the NTSB, the accident pilot received SS2 systems and procedures ground training on November 26, 2013. The accident co-pilot received a ground review of SS2 cautions and warnings, annunciators and emergency procedures on September 3, 2013. He also received WK2 systems training from May 17-20, 2013.[73]

11.2 SS2 Simulator

14 CFR 460.7 (b) Operator Training of Crew, stated in part:

> *(b) Training device fidelity. An operator must*
>
> > *(1) Ensure that any crew-training device used to meet the training requirements realistically represents the vehicle's configuration and mission, or*
> >
> > *(2) Inform the crew member being trained of the differences between the two.*

The SS2 simulator was a fixed-based simulator (non-motion) replicating the SS2 cockpit. Both Scaled Composites and Virgin Galactic pilots trained in the SS2 simulator located at the Scaled Composites facilities at Mojave, CA.[74] The simulator had partial dome spherical projection screen visual displays, and did not have a “freeze” function. The feather lock handles had gates requiring a rightward movement of the handles within the console before actuation, and Scaled Composites and Virgin Galactic SS2 test pilots indicated that the feather lock levers in the simulator moved more easily than the feather lock levers on the actual vehicle.

The Primary Flight Displays (PFD) in the SS2 simulator incorporated new indications of trim positions that had not been present on powered flights prior to PF04. The new trim indications on the PFD were also present on SS2.[75] According to the accident pilot, the idea of the new trim settings indication on the PFD came from SpaceShipOne (SS1), which had the trim setting on the PFD[76], and he said it might be nice to have that on the SS2 PFDs, but it was not required. He believed the new indicator was being worked by the Virgin Galactic team for consideration for commercial operations, and they flew an early concept of that display for this flight (PF04). He said they started flying simulations with the new trim display about three or four weeks prior to

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[73] See Attachment 7 – Ground Training Syllabus, and Attachment 8 – WK2 Training Syllabus.
[74] Virgin Galactic also had a simulator located at its facilities at Mojave, CA. At the time of the accident, the cockpit configuration replicated the WK2 cockpit.
[75] For additional information on the trim settings display on the PFD, see System Group Chairman’s Factual Report.
[76] SS1 had a single display whereas SS2 has 3 displays: two normally configured as PFD’s in front of each pilot and one centrally mounted MFD.

the accident, and he was not aware of any additional risk or hazard analysis done for the new display.[77]

According to Scaled Composites, the SS2 simulator included the following features:

Detailed duplication of the SS2 cabin layout: avionics, switches, controls, windows, etc.
Wrap around video simulation and sound effects.
Detailed and precise SS2 flight dynamics.
The ability to simulate both control forces and effectiveness in all flight regimes.
The ability to simulate wind profiles.
The ability to simulate thrust asymmetries
The ability to simulate a huge array of failure conditions.

Based on simulator testing conducted by the NTSB on November 4, 2014, the Scaled Composites SS2 simulator did not model an uncommanded feather with the feather unlocked at 0.80 Mach during transonic flight.[78]

Before each mission, a Test Pilot and Flight Test Engineer used the simulator for initial mission planning and test point specification. After the objectives and test points were refined, the entire mission team (including the control-room personnel) conducted full mission rehearsals (integrated simulations).[79] During those mission rehearsals the team worked through both normal and emergency procedures and abort scenarios. Based on evaluation of the results of those mission simulations by the responsible pilots and engineers, the Normal Procedures (NPs) , Emergency Procedures (EPs) and the flight test data cards were updated as required prior to each flight. Those changes were also captured in the ground station's mission notebooks.[80]

The SS2 simulator had an operator's console that was used to load and run training scenarios and to stimulate faults and failures. The console also had the capability of feeding simulated data to the control room for full-up control-room-in-the-loop mission simulation (integrated simulations). According to Scaled Composites, data generated from the simulator during those simulations (i.e. flight profiles flown by the pilots, control positions measured, etc.) was available for download only when the control room was activated. The data was not downloadable for simulator sessions where the pilots operated the simulator separate from the control room (i.e. when the pilots practiced profiles in the simulator without incorporating the control room in their practice).

The SS2 simulator generated information that could be used to track flight crew proficiency. Each time the simulator was started, the pilot and co-pilot names were selected, and that data was appended to a log file which included the date, time, simulated wind information, simulator state information, and initial condition information.[81]

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77 See Attachment 1 – Interview Summaries.
78 See Attachment 10 – SS2 Simulator Test Plan.
79 For further information, see Section 11.3 Integrated Simulations of this Factual Report.
80 See Section 14.0 Ground Station of this Factual Report.
81 See Attachment 14 Simulator Logs.

According to SS2 test pilots, when pilots were in the simulator for training, they primarily wore regular clothing, and rarely trained in the simulator in the clothing worn during a test flight (flight suit, helmet, oxygen mask, gloves).

Both accident pilots conducted training in the SS2 simulator multiple times leading up to PF04 that did not include activation of the control room (integrated simulation).[82] The first opportunity for the accident pilots to train with a version of the PF04 flight test data card was following the initial release of the test card on July 11, 2014. According to Scaled Composites SS2 simulator logs, the accident crew conducted simulator training on the following dates after the initial release of the PF04 flight test data card (times listed in Pacific Daylight Time):

August 12, 2014 at 0725:56 – accident crew trained together
August 12, 2014 at 1256:26 – accident crew trained together
August 18, 2014 at 1200:46 – accident crew trained together
August 21, 2014 at 0832:23 – accident crew trained together
August 26, 2014 at 1156:20 – pilot trained in the right seat
August 27, 2014 at 1244:05 – accident crew trained together
September 3, 2014 at 1452:58 – pilot trained in the left seat
September 22, 2014 at 0807:38 – accident crew trained together (integrated simulation)
September 22, 2014 at 1325:31 – pilot trained in the right seat
September 23, 2014 at 0709:35 – pilot trained in the right seat
September 23, 2014 at 1105:09 – pilot trained in the left seat
September 29, 2014 at 0636:23 – accident crew trained together (integrated simulation)
September 30, 2014 at 1446:46 – pilot trained in the right seat
October 2, 2014 at 1325:13 – pilot trained in the left seat
October 3, 2014 at 0718:18 – pilot monitored (integrated simulation)
October 3, 2014 at 0849:22 – pilot trained from the right seat
October 3, 2014 at 1304:11 - the pilot occupied the right seat
October 6, 2014 at 1130:13 – the pilot occupied the right seat
October 6, 2014 at 1435:48 – the pilot occupied the left seat
October 10, 2014 at 1346:30 – copilot trained in the right seat
October 13, 2014 at 0801:31 – accident crew trained together (integrated simulation)
October 14, 2014 at 0536:44 – accident crew trained together
October 14, 2014 at 1052:22 – pilot trained in the left seat
October 14, 2014 at 1541:19 – pilot trained in the left seat
October 15, 2014 at 1327:40 – pilot trained in the left seat
October 17, 2014 at 1251:28 – pilot trained in the left seat (integrated simulation)
October 21, 2014 at 0630:19 – accident crew trained together
October 21, 2014 at 0730:08 – accident crew trained together (integrated simulation)
October 27, 2014 at 0611:24 – accident crew trained together (integrated simulation)
October 28, 2014 at 0635:31 – copilot trained in the left seat
October 28, 2014 at 0841:41 – accident crew trained together
October 28, 2014 at 1513:32 – pilot trained in the left seat
October 29, 2014 at 1523:33 – pilot trained in the left seat
October 30, 2014 at 0723:58 – accident crew trained together

[82] See Section 11.3 Integrated Simulations of this Factual Report.

11.3 Integrated Simulations

Scaled Composites trained in preparation for PF04 using "integrated" simulations that involved scenario-based training in the SS2 simulator along with activation of the Ground Station (control room) for full-team mission rehearsals. According to the Director of Flight Operations, Scaled Composites had an internal policy of conducting a minimum of three integrated simulations prior to a boost flight. According to Scaled Composites records, there were eight integrated flight simulation training sessions leading up to PF04. Each session included multiple flight scenarios in which the crew members were presented with a combination of scenarios, either leading to an abort and execution of emergency procedures, or to a landing. The dates and scheduled times of the integrated simulations for PF04 were:

- October 27, 2014 0730-0930: PF04 simulation, integrated
- October 21, 2014 0730-0930: PF04 simulation, integrated
- October 17, 2014 1330-1530: PF04 simulation, integrated
- October 13, 2014 0730-0930: PF04 simulation, integrated
- October 3, 2014 0730-0930: GF30 simulation, integrated
- September 29, 2014 0730-0930: PF04 simulation, integrated
- September 22, 2014 1300-1500: GF30 simulation, integrated
- September 22, 2014 0730-0930: PF04 simulation, integrated
  (Times listed here are local Pacific Daylight Time)

On October 30, 2014, the Scaled control room conducted a "re-run" of PF03 at 1300 PST for Scaled Composites Ground Station (control room) personnel to review data at their stations consistent with what would be viewed the next day. The SS2 simulator was not used in the PF03 "re-run." The PF04 pilot participated, viewing data on the control room MFD.

The Scaled Composites experimental permit, Section 5.1.2.1 Simulator, stated the following:

> *During these mission rehearsals the team works through both normal and emergency procedures and abort scenarios. These mission simulations are practiced in accelerated time (typically 1.4 times real time) so that the crew is well trained to timely respond to mission issues.*[83]

One of the considerations by the FAA when it issued the July 18, 2013 waiver to Scaled Composites for compliance with 14 CFR 437.55(a) was the Scaled Composites training program. Included in the training program was Scaled Composites' use of the simulator. The July 18, 2013 FAA waiver stated the following, in part:

> *Scaled runs its simulator 1.4 times faster than actual flight in order to ensure that pilots and ground crew are trained to respond quickly to various flight conditions and*

[83] Scaled Composites experimental permit, Section 5.4.2, Mission Planning, stated "these mission simulations are sometimes practiced in accelerated time (typically 1.4 times real time) so that the crew is well trained to timely respond to mission issues."

anomalies. By practicing various nominal and non-nominal scenarios in the SS2 simulator, pilots are able to rehearse how to operate the SS2. This training also enhances the speed and reaction time of the crew, and allows the crew to practice working together to run various procedures, such as going through the checklist.

Interviews with Scaled Composites test pilots indicated that the simulator had not been operated using the 1.4 times recently, and was primarily used during training for SS1. According to the Scaled Composites Director of Flight Operations, he could not remember the last time the simulator was run at 1.4 times speed, but thought it had been a while since that feature was utilized. A review of PF04 integrated simulator session data indicates that all recorded sessions were run at the 1.0x (real time) rate during the boost phase.

11.4 WK2 Training

WK2 was used by the SS2 flight crew for proficiency training and simulating glide through landing flare. The WK2 cockpit layout was similar (by design) with the SS2 cockpit, and with the WK2 gear down and inboard speedbrakes extended and engines set to 75% N2, the WK2 had a similar flight path and descent profile to SS2. As stated in Scaled Composites' Experimental Permit Application, SS2 pilots conducted at least three WK2 simulated approaches for proficiency prior to an SS2 powered flight.

According to Scaled Composites records, the accident pilot last flew WK2 as a co-pilot on July 22, 2014 (Flight 155) in preparation for upcoming SS2 glide flights and PF04. The WK2 test card from that flight indicated he flew two SS2-like approaches as pilot flying, and one as pilot monitoring. He also conducted one touch and go in WK2. On January 15, 2014 (Flight 148) the accident pilot conducted three SS2-like approaches as pilot flying, and four as pilot monitoring. He also conducted one touch and go and one full stop landing in WK2. According to Scaled Composites, the accident pilot had flown 60 flights in WK2 as pilot/co-pilot/instructor pilot from the period of December 2008 to July 2014.[84]

According to Scaled Composites records, the accident co-pilot last flew as co-pilot on WK2 (Flight 170) on October 7, 2014. The WK2 test card from that flight showed he flew one SS2-like approach as pilot flying, and one as pilot monitoring. He also conducted one touch and go in WK2. According to Scaled Composites, the accident co-pilot flew 18 flights in WK2 as co-pilot from the period June 2009 to October 2014.[85]

11.5 Extra EA300/L Training

14 CFR 460.5 Crew Qualifications and Training, stated in part:

(b) Each member of a flight crew must demonstrate an ability to withstand the stresses of space flight, which may include high acceleration or deceleration, microgravity, and vibration, in sufficient condition to safely carry out his or her duties so that the vehicle will not harm the public.

[84] See Attachment 13 – Pilot WK2 Training.
[85] See Attachment 13 – Pilot WK2 Training.

According to the Scaled Composites experimental permit, before SS2 powered flights, the SS2 pilots received aerobatic training in an Extra EA300/L for "g" tolerance,[86] motion sickness, unusual attitudes, and landing patterns. The Extra EA300/L was operated by Virgin Galactic, and the training was conducted based on a syllabus defined on a test card.[87] The syllabus included training in positive and negative "g's", rapid "g" onset (Gamma[88] turn simulation), adverse reentry "g" training, and disorientation and recovery training. According to Scaled Composites, it was their internal policy to conduct a minimum of three training sessions in the Extra EA300/L in preparation for a powered flight, including gaining and maintaining "g" tolerance and upset recovery training.

The accident pilot flew as a flight crew member on three Extra EA300/L flights in preparation for P04; once on October 2, 2014, once on October 9, 2014 and once on October 15, 2014. A Virgin Galactic test pilot served as PIC on each of those flights.[89]

The accident co-pilot flew as a flight crew member on three Extra EA300/L flights in preparation for PF04; once on August 5, 2014, once on October 14, 2014, and once on October 21, 2014. A Virgin Galactic test pilot served as PIC on each of those flights.[90]

The FAA waiver issued to Scaled Composites and published in the Federal Register (Federal Register / Vol. 78, No. 138) on July 18, 2013 stated, in part:

> . . . *as part of ongoing g tolerance training, the SS2 crew completes an aerobatic training course that covers g tolerance, motion sickness, and unusual attitudes. This training is performed in a small aerobatic aircraft. SS2 crew may also train in a g tolerance training device, such as a centrifuge.*

According to the Director of Flight Operations, Scaled pilots did not receive centrifuge training in preparation for SS2 boost flights, and it was not part of Scaled training. They used the Extra EA300/L as a centrifuge surrogate for high "g" and upset training to satisfy the objectives achievable through centrifuge training.[91]

12.0 Relevant Systems

12.1 SS2 Flight Controls

The primary flight control system of SS2 was a mechanical, reversible system consisting of elevons for pitch and roll control and rudders for yaw control. Elevon cockpit control was by a yoke shaped center stick. Rudder cockpit control was via rudder pedals. There was a dual set of connected controls for both the pilot and co-pilot.

[86] "G" was a measure of gravitational force, where 1 "g" was equal to the force of gravity at the Earth's surface.
[87] See Attachment 9 – Extra Training Syllabus.
[88] The "gamma turn" refers to the vehicle's increasing pitch up to vertical following rocket motor ignition.
[89] See Attachment 14 – Pilot Extra Training.
[90] See Attachment 14 – Pilot Extra Training.
[91] See Attachment 1 – Interview Summaries.

12.2 Feather System

The SS2 used a feather system to aerodynamically configure the vehicle for reentry. Extension and retraction of the feather on the SS2 was a two-step process. To extend the feather for reentry, the pilots would first unlock the system by moving the connected unlock handles on the center console (See Photo 3 in Section 12.3 Feather Lock/Unlock Handles, of this Factual Report) down to the unlock position and then extend the feather by pulling two connected handles. The status of the feather and lock system was monitored through indicator lights in the cockpit, a full-time display field on the center MFD, and in detail on a crew-selectable feather systems page on the MFD.

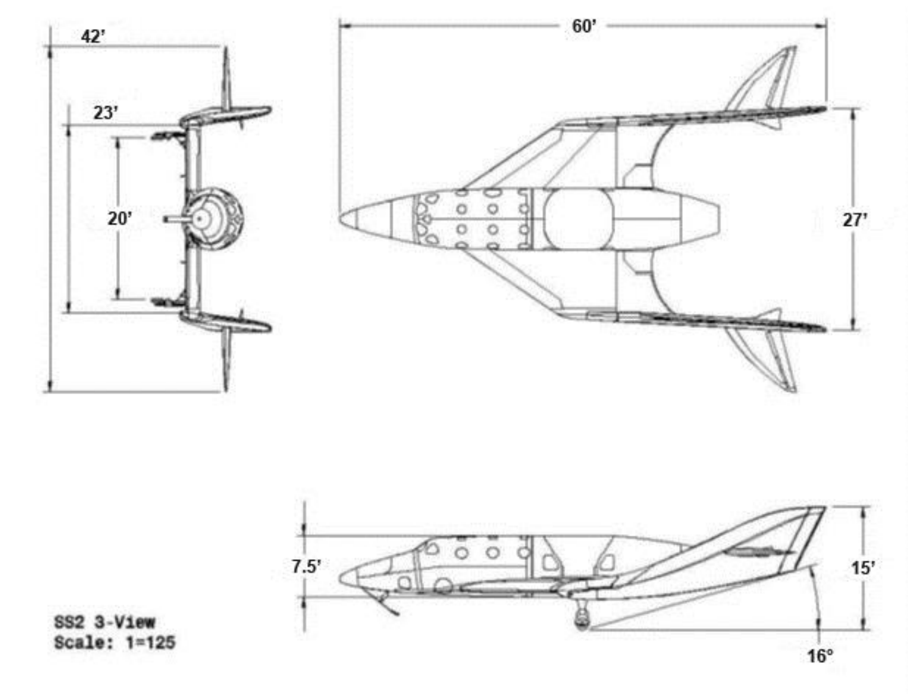

Figure 4: SS2 Feather Down configuration.[92]

[92] Source: Scaled Composites.

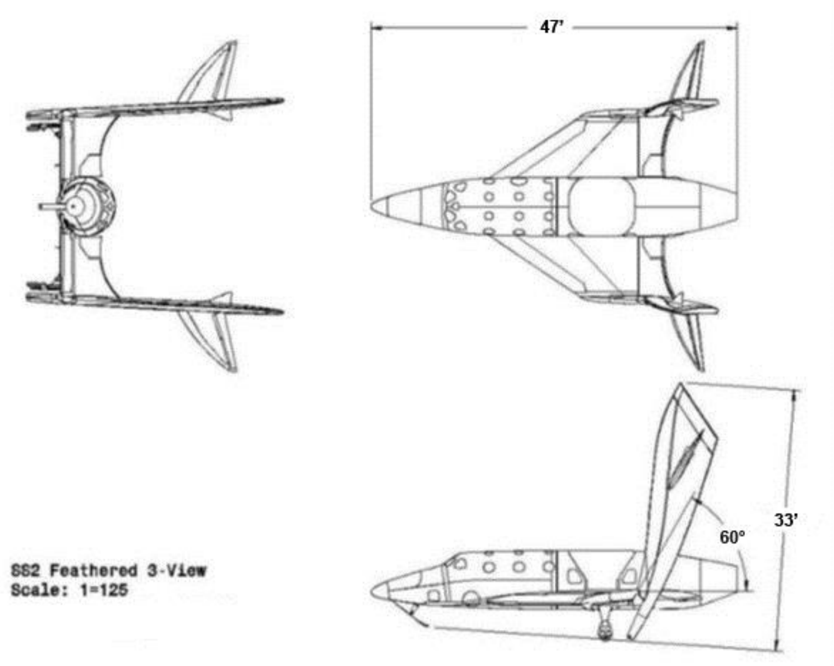

Figure 5: SS2 Feather up configuration.[93]

When the feather was not extended, it was locked in the unfeathered position (see Figure 4). The feather locks were a mechanical system that locked and unlocked the feather on the SS2. When the two feather locks were opened (unlocked), the feather actuators in the aft fuselage, when commanded, could rotate the feather assembly upward 60° to place the vehicle in the feathered configuration for reentry (see Figure 5).[94]

[93] Source: Scaled Composites.
[94] Source: SS2 POH (SS2-90P001 REV D – 3 dated September 2013), page 98. For a detailed description of the feather and feather locking system, see Systems Group Chairman's Factual Report.

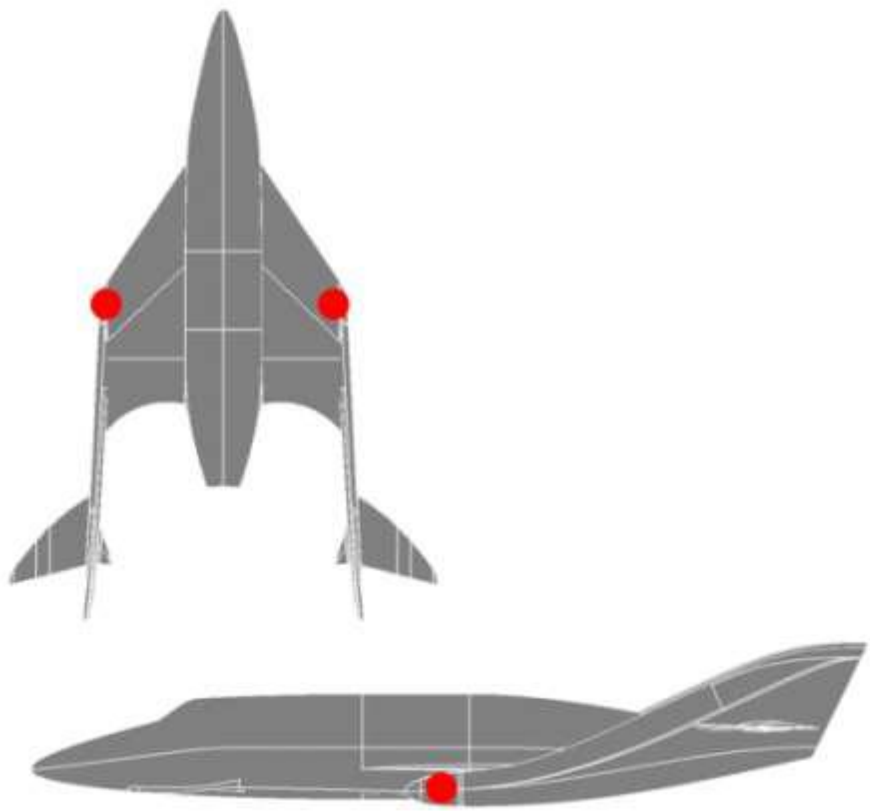

Figure 6: Feather lock locations.[95]

12.3 Feather Lock/Unlock Handles

The feather must first be unlocked by the pilots before the feather handles could be pulled, deploying the feather. To unlock the feather, the pilot moved the unlock handles located on the center console downward to their mechanical stop. To lock the feather, the pilot returned the handles to the up stop. The feather locks actuated within one to two seconds of the feather handles reaching full travel. The feather lock handles were held in the locked or un-locked positions by small gates. The gates prevented the handles from moving under normal vibration. To move the handles, a slight side force to the right side would allow the handles to move past the gates.

[95] Source: SS2 POH (SS2-90P001 REV D – 3 dated September 2013), page 98.

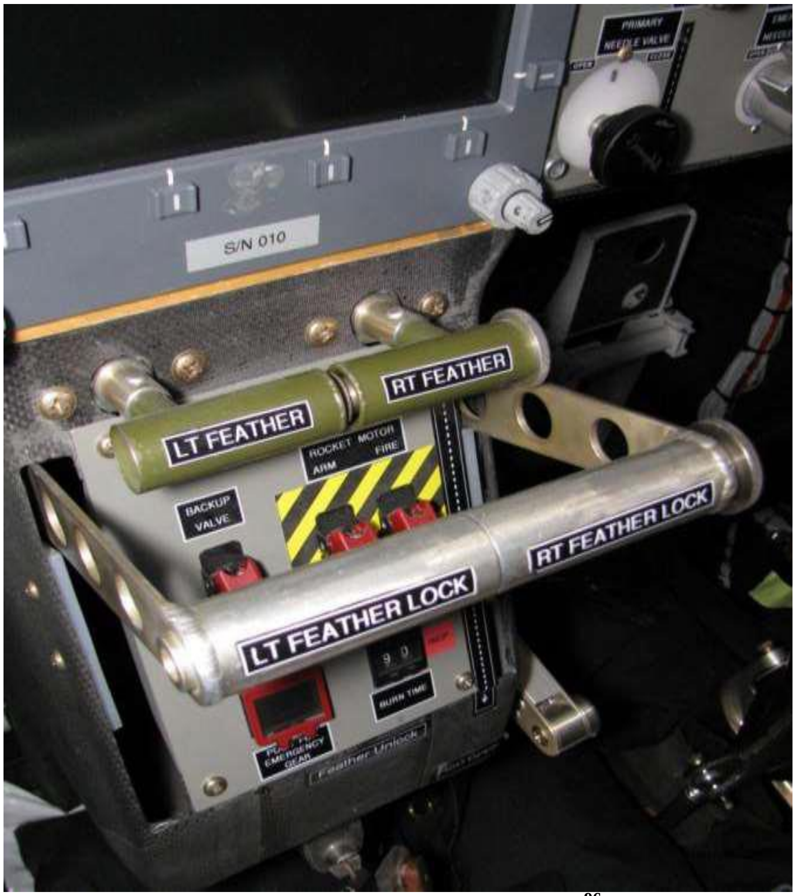

Photo 3: SS2 Feather Lock and Actuation Handles.[96]

The feather lock handles (left lock and right lock) were pinned together. Under normal feather lock actuation, the handles were manipulated as one and remained pinned together. The pin could be removed and the right and left handles could be moved independently. In a response to an NTSB inquiry as to which emergency procedure a pilot would reference to operate the unlock handles independently, Scaled Composites replied:

> *The initial intent for both the feather actuation and lock systems was to be able to split the systems at the handle to mitigate a jam of the controls, linkages and valve in the crew station. As has been discussed elsewhere, the unlock procedure was added very early in T1b (07'). The mechanism for actuating the system was also designed/fabricated very early in the program (07-08'). The system and procedures were developed over many years. As we developed the procedures to safely unlock during boost we became aware there was insufficient time for the pilot to identify a system failure and split the lock handles. Therefore, an EP was never developed*.[97]

The feather lock system was a binary system. The crew station handles were not intended to provide intermediate control of the feather locks. The feather lock handles should be deliberately placed in either the full-up (locked) or full-down (unlocked) position at all times. Intermediate

[96] Source: SS2 POH (SS2-90P001 REV D – 3 dated September 2013), page 105.
[97] Response to March 04, 2015, received from Scaled Composites on March 7, 2015.

handle positions could lead to damaged hardware or an unsafe flight condition. The crew station handles were designed to minimize the chance of accidentally activating the feather out of sequence. According to the SS2 POH, because of the handle geometry, the feather was intentionally difficult to actuate while the feather was in the locked position; the feather must be unlocked first.[98]

14 CFR 460.15 Human factors, stated in part:

> *An operator must take the precautions necessary to account for human factors that can affect a crew's ability to perform safety-critical roles, including in the following safety critical areas*
> *(a) Design and layout of displays and controls;*
> *(b) Mission planning, which includes analyzing tasks and allocating functions between humans and equipment.*

For human factors elements associated with this accident, see the Human Factors Group Chairman's Factual Report.

13.0 Relevant Procedures

The normal SS2 pilot procedures for preflight, flight, and post-flight were defined in the SS2 Normal Procedures manual (SS2-90P002, Revision J, Change 5, dated 14 October 2014). Generally, checklists from the Normal Procedures manual were referenced by pilots to accomplish required tasks based on the phase of flight.[99]

The SS2 Normal Procedures manual, page 5, stated (in part):

> *This checklist is designed so the important checklist steps and procedures are contained on the right (odd numbered) pages. Additional information is provided as appropriate on the left (even numbered) pages in the forms of NOTES (amplifying information that is not required for checklist accomplishment but may be of interest to the aircrew), CAUTIONS (information that if not followed may result in damage to vehicle systems), and WARNINGS (information that if ignored could cause serious injury or death).*

According to the SS2 Normal Procedures manual (page 35) for normal boost flight, the pilot procedures for an SS2 launch prior to release included the following:

1. "20, 10, 5, 4, 3, 2, 1, Release, Release, Release"
2. PYLD RELEASE – PRESS (momentary)[100]
3. PF – Report clean release (or "ARMED" if briefed)
If Rocket Flight

[98] Source: SS2 POH (SS2-90P001 REV D – 3 dated September 2013), page 100.
[99] For exceptions when the pilots did not reference the checklists in the Normal Procedures manual, see Section 10.4 Flight Test Data Card of this Factual Report.
[100] Steps one and two are performed by WK2 crew as noted by the different color for the text in the Normal Procedures.

4. PNF – RM ARM/SAFE – ARM [3 green igniters]
5. PF – Head against headrest, stiff shoulders and firm grip
6. PNF [at PF's command] – RM FIRE – FIRE
7. PNF — Head against headrest

During the boost portion of the flight, the SS2 Normal Procedures manual (page 37) included the following:

1. Stick – maintain < 15° AOA
When >0.95 Mach (after pitch bobble)
2. Pitch Trim – Set –15.0 NU (or per flight card)
@ >1.4 Mach[101]
3. PNF FEATHER -- UNLOCK
4. Pitch Trim – as required to capture zenith

13.1 Pilot Boost Procedures

Mission-specific information for PF04 was included on the PF04 flight test data card (Revision U).[102] This card included vehicle restrictions and limitations, weight and balance information, performance information, mission timeline information, and expected pilot actions during the various phases of flight.

During the boost portion of the flight, the pilot tasks were defined in the flight test data card. According to SS2 pilots, these were memorized tasks performed without reference to a Normal Procedures checklist for the boost portion of the flight. This was due to the dynamic nature of the boost phase, and because the pilot workload during the boost phase was high and prevented the pilots from pulling a checklist out to reference.

According to the PF04 flight test data card, the following items were memorized procedures for the SS2 pilots during the boost phase:[103]

COPILOT
CALL – 0.8M

PILOT
After transonic bobble – TRIM to -14.0 NU

COPILOT
CALL – Stabs (degrees)
1.4M – FTHR: UNLOCK

[101] The procedure to unlock the feather system on the SS2 at 1.40 Mach was introduced when Scaled Composites began using the rocket system components on SS2, and first appeared in the SS2 Normal Procedures (Revision F) in November 2012. The 1.40 Mach unlocking procedure had been a part of each subsequent revision of the SS2 Normal Procedures.
[102] The PF04 flight test data card was initially drafted on July 11, 2014 with revision IR (initial release). There were multiple revisions to the test card leading up to the final version used for PF04 (Revision U).
[103] See Section 13.1.1 SS2 PF04 Pilot Tasks of this factual report.

The following sections of this Factual Report show the portions of the flight test data cards that included the pilot tasks defined during various portions of flight during the four boost flights of SS2.

13.1.1 SS2 PF04 Pilot Tasks

#	Maneuver	kft	PILOT	COPILOT
A	RM2 Burn	46	• After transonic bobble – TRIM to -14.0° NU	• CALL – 0.80M • CALL – Stabs (degrees) • 1.4M – FTHR: UNLOCK
B	Coast	80	• Pitch: Capture Red Circle • Goal = vertical	• RM2 Sw's (L←R) – OFF (2") (b) (4) OFF
C	Feather	135	• ROLL BOOST - OFF • PRI RCS – ENABLE • Pitch–Belly down • RCS – 3 axis eval **When ϒ ~ +20°**	• FTHR: EXTEND • Trim to -10° NU/+0.5Roll
D	Reentry	60	**When > 40 KEAS** • RCS – DISABLE • DAMPERS – Verify ON • ROLL BOOST – A/R **When <60K' or <1.3Nz** • ROLL BOOST – A/R • 10° α dive recovery	• Trim to -10° NU/+0.5Roll **When <60K' or <1.3Nz** • FTHR: RETRACT
E	N20 Dump	40	**0.5g < Nz < 2.7g & <10°α** • DAMPERS – OFF (<0.8M) • S/B – ENABLE • Left Window Heat - Auto • ≥ 160 KEAS	• N2O AUTO DUMP – ON • PSC – Verify **ACTIVE** *When MOT @ 160 PSI* • N2O AUTO DUMP– OFF (b) (4) RUN - ON
F	Landing		• **HK360 WIF L / R RWY 30 / 12 / 26 / 08**	

Figure 7: PF04 Flight Data Test Card (Card 7) flown October 31, 2014

13.1.2 SS2 PF03 Pilot Tasks

#	Maneuver	H~ kft	PILOT	COPILOT
A	RM2 Burn	46	• > M1.0 – TRIM to -14.0° NU	• Feather LOCKS – UNLOCK @ 1.3M
B	COAST	65	• Pitch: Capture +60° ϒ • @ 80 KEAS – pitch to 30° θ • <50 KEAS o PRI RCS – ENABLE o Pitch: Capture 30° θ o Roll: Level	• RM2 Sw's (R→L) – OFF/SAFE/CLOSED • PSC – OFF • ULLAGE – VENT <650 PSI
C	Feather	60	• When ϒ < 0° o ROLL BOOST – OFF o Yaw RCS: 2s burst L & R o PRI RCS – DISABLE • 10° α dive recovery • ROLL BOOST – A/R	• FTHR: UP • Trim to -10° NU • ~50K' FTHR: DOWN
D	N20 Dump	40	• 0.5g < Nz < 2.7g and <10°α • DAMPERS – OFF (<0.8M) • S/B – ENABLE • > 160 KEAS	• N2O AUTO DUMP – ON • PSC – ENABLE • N2O AUTO DUMP- OFF @160 PSI
E	App to stall	28	• ≥ 100 KEAS	• ≤ 20°AOA
F	Dutch Roll	20	• Rudder doublets at • 200 KEAS, 165 KEAS	
G	Landing		• **HK360 WIF L / R RWY 30 / 12 / 26 / 08**	

Figure 8: PF03 Flight Test Data Card (Card 8) flown January 10, 2014.

13.1.3 SS2 PF02 Pilot Tasks

#	Maneuver	H ~ kft	PILOT	COPILOT
A	RM2 Burn	46	• Hold trim until post transonic pitch-up • Max transonic: 15° α • > M1.0 – TRIM to -13° NU	• Feather LOCKS – UNLOCK @ 1.2M
B	COAST	65	• Allow nose to rise until <0.80 Mach (no trim) • Then TRIM to -5° NU	• RM2 Sw's (R-L) – OFF/SAFE/CLOSED • PSC – OFF • ULLAGE – VENT for "one mississippi", then OFF
C	Feather	50	• ROLL BOOST - OFF • TRIM to -10° NU • 10° α dive recovery	• Feather—UP when ↓ γ & < 100 keas • Feather —DOWN ≥ 50K'
D	N20 Dump	36	• Maintain 0.5g < Nz < 2.7g and <10°α • DAMPERS, S/B, ROLL BOOST – OFF • Control transfer • Monitor AUTO DUMP	• N2O AUTO DUMP • If PSC Fault – verify <780 PSI & cycle C/Bs • PSC – ENABLE
E	Copilot Landing		WIF **L / R** Rwy **30 / 12 / 26 / 08**	

Figure 9: PF02 Flight Test Data Card (card 8) flown September 5, 2013.

13.1.4 SS2 PF01 Pilot Tasks

#	Maneuver	H~ kft	Parameter
A	RM2 Burn	46	• Hold trim until transonic (~.90-.95) • Max transonic: 12° α • Trim to -12° NU for gamma turn • Trim down at burnout for point B
B	Parabolic Arc	52	• Target ~0.5g Nz untill increasing KEAS • RM FIRE – OFF • RM ARM/SAFE – SAFE • BOV - CLOSE
C	N20 Dump	36	• Maintain 0.5g < Nz < 2.0g • AUTO DUMP – ON • Monitor AUTO performance A/R
D	Arrival at HIKEY	12	On track, on energy
E	Landing		WIF **L / R** Rwy **30 / 12 / 26 / 08**

Figure 10: Flight Test Data Card for PF01 (Card 8) flown April 29, 2013.

13.2 0.80 Mach Callout

After the rocket motor was fired and when the vehicle reached 0.80 Mach, the PF04 flight test data card called for the co-pilot to make a "0.8 Mach" callout to alert the pilot that they would be transitioning 1.00 Mach (transonic) and to anticipate a transonic "bobble." This bobble was a phenomenon where the vehicle pitched up then pitched down due to aerodynamic forces and a shift in the center of lift on the vehicle. The 0.80 Mach callout was designed to give the pilot flying additional situational awareness prior to the bobble. There was no physical action required of the co-pilot based on the 0.80 Mach callout. According to the accident pilot, the 0.80

Mach callout was designed to give the pilot flying information that the bobble was about to occur. He further stated that the boost phase was a very dynamic environment, and the pilot workload was extremely high. [104]

According to interviews, the 0.80 Mach callout originated following de-briefs of PF01. According to the pilot of PF01, the 0.80 Mach callout by the pilot monitoring "was a technique he came up with to prepare for the pitch up. From PF02 on, he briefed 0.80 Mach as a call."[105] Flight test data cards for PF02 and PF03 did not include the 0.80 Mach callout. Review of cockpit audio recordings showed that the 0.80 Mach callout was made by the pilot monitoring during PF03. The 0.80 Mach callout was first included on the flight test data card for PF04, and was included as a callout by the co-pilot on its initial release of the PF04 flight test data card on July 11, 2014. It remained on all subsequent revisions of the test card through the final version (Revision U).[106] According to Scaled Composites, pilots always used the most current test card for PF04 simulator sessions.

According to interviews with SS2 pilots, the co-pilot would reference the digital Mach readout on the upper left of his PFD to determine when to make the 0.80 Mach callout (See Photo 4).[107] As the SS2 vehicle accelerated through 0.80 Mach, the source of airspeed data for each display transitioned from the ADC (Air Data Computer) to the INS (Inertial Navigation System) when the AUTO mode was selected for that display (the normal configuration for boost flight). With the displays in AUTO, the transition from ADC to INS occurred at either a speed above 0.80 Mach, an altitude above 60,000 feet, or when the feather was not down. In addition, when the airspeed and altitude sources changed from ADC to INS, the background of the equivalent airspeed and altitude indicators on each PFD would change from black to grey (see Photo 4) and the mode indicator would change from A to I.[108]

[104] See Attachment 1 – Interview Summaries.
[105] See Attachment 1 – Interview Summaries.
[106] Source: Scaled email to the Operations Group Chairman on January 22, 2015.
[107] The airspeed indicator to the upper left of the PFD display showed a digital readout of airspeed in KEAS (Knots Equivalent Airspeed). KEAS is the calibrated airspeed corrected for adiabatic compressible flow for a particular altitude.
[108] For further information, see System's Group Chairman's Factual Report.

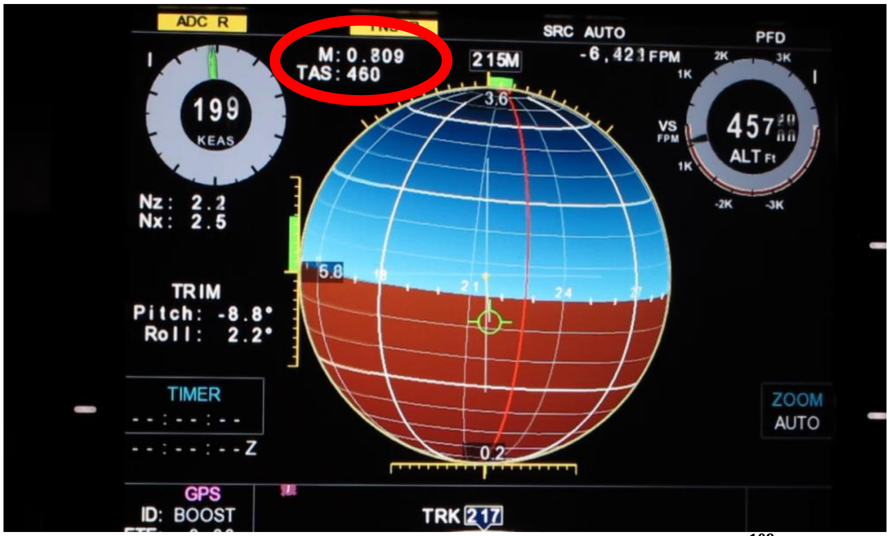

Photo 4: Pilot's PFD. Mach indicator (M) indicated by red circle.[109]

13.3 Unlocking of the Feather

For PF04, during the boost phase, the feather locks were to be unlocked by the co-pilot at 1.40 Mach in the latter portion of the gamma turn maneuver, based on the PF04 Flight Test Data Card. The locks were supposed to remain unlocked until the feather was retracted at the end of the reentry (at approximately 60,000 feet) and the MFD "OK TO LOCK" message and back-up panel light illuminated.[110]

For reentry, the feather was required to be unlocked so the feather could be extended by the pilots once the vehicle neared apogee (approximately 135,000 feet for PF04). The unlocking of the feather occurred during the boost phase. Prior to launch, the SS2 pilots performed a check of the feather locks during preflight of the vehicle on the ground and during the L-10 (ten minutes prior to release) checklist per Normal Procedures. The SS2 crew tested the feather locking system by unlocking the feather while still mated to WK2 and verifying the indications on the MFD. After verifying proper operation of the feather, the pilots locked the feather before release from WK2. There were no anomalies detected in testing of the feather locks.

After launch and rocket motor ignition, the vehicle would accelerate toward the transonic phase of flight (approximately 0.90 -1.20 Mach). Upon reaching 1.40 Mach, the co-pilot was required to unlock the feather. The unlocking of the feather was defined in the SS2 Normal Procedures (page 37), which stated:

> ***BOOST PHASE***
> *1. Stick – maintain < 15° AOA*
> ***When >0.95 Mach (after pitch bobble)***
> *2. Pitch Trim – Set –15.0 NU (or per flight card)*
> ***@ >1.4 Mach***
> *3. PNF FEATHER -- UNLOCK*

[109] Source: NTSB Systems Group Chairman's Factual Report.
[110] Source: SS2 POH (SS2-90P001 REV D – 3 dated September 2013), page 100.

4. Pitch Trim – as required to capture zenith

As previously mentioned, the memorized boost procedures for the co-pilot were defined in the PF04 Flight Test Data Card, and stated:

COPILOT
CALL – 0.80M
CALL – Stabs (degrees)
1.4 Mach – FTHR UNLOCK

If the feather was not unlocked by 1.50 Mach, the pilots would receive a Crew Alert System (CAS) aural/visual alert "FEATHER LOCKS" on the upper right display area on the center MFD. If the feather was not unlocked by 1.80 Mach, procedurally the pilots were required to abort the rocket motor burn. If the feather could not be unlocked, the crew would be required to accomplish an unfeathered reentry of the vehicle. This abort for a jammed or nonoperational feather lock was required before 1.80 Mach in order to limit the apogee. The SS2 Emergency Procedures manual, page 83 "Feather Locks Fail To Open" stated:

If EITHER feather lock fails to UNLOCK
1. RM2—ABORT
2. FEATHER — Leave DOWN and fly parabolic recovery
If >1.8 Mach
3. Go to FEATHER DOWN REENTRY

According to interviews with SS2 pilots and Scaled Composites engineers, unfeathered reentry from maximum apogee could result in very high g-loads, very high speeds, and there was a concern about flutter and heat loads on the vehicle.[111]

The feather was originally tested on flight GF07. Additional feather extensions occurred on GF10, GF16, GF20, GF21, GF24, GF26, PF02, PF03, and GF30.

The pilot monitoring of the two previous powered flights of SS2 also unlocked the feather during the boost phase. For PF02 and PF03, the feather was unlocked by the pilot monitoring at 1.20 Mach and 1.30 Mach, respectively. Both flights were not anticipated to reach a speed of 1.40 Mach due to the limited duration of the rocket motor burn (20 seconds for each of those powered flights). The pilots of PF01 did not unlock the feather during boost because the burn was only 16 seconds long.

The feather was not unlocked during the boost phase for SS1 powered flights. According to the Tier1B Program Manager, during the SS1 program the feather was unlocked immediately before feather extension.[112] The existence of single-point failures that would prevent feather extension

[111] See Attachment 1 – Interview Summaries.
[112] According to the Tier1B Program Manager, during the SS1 days, the feather was unlocked when they needed it. They knew they had single point failures in SS1 in that if the locks failed, the feather would not unlock. They knew the feather was needed to reenter safely, so they added redundancy which also then introduced more failure modes. In SS2, they minimized the risk of a jammed feather lock by unlocking the feathers prior to rocket motor burnout

was known at the time of the SS1 program. The team knew the feather was needed to reenter safely from maximum apogee. According to Scaled Composites, on SS2 they procedurally mitigated the risk of a failure mode involving a jammed feather lock by unlocking the feather prior to cessation of thrust.[113]

According to multiple interviews with Scaled engineers, the feather system was unlocked during boost as a risk mitigation to avoid having the feather system remain locked after 1.80 Mach requiring an unfeathered reentry from maximum apogee. There was a recognized risk to unlocking the feather prior to 1.40 Mach because unlocking the feather when the tails were generating a large lifting force could overpower the feather actuators. The former Scaled Composites Chief Aerodynamicist said that Mach 1.40 was established as the speed to unlock in order to give a sufficient margin of safety from the regime where there was an upward lift on the tail. He recollected that at about Mach 1.10 there was a down force on the tail, and from 0.80 to 1.00 Mach there was an upward lift on the tail before it switched to a down force. The development team created the procedure calling for the pilots to unlock the feather during the boost. This provided the opportunity to abort the boost by 1.80 Mach if the feather remained locked and thereby avoid a feather-down reentry from maximum apogee.[114]

The SS2 accident pilot knew the feather should not be unlocked prior to 1.40 Mach, but he could not remember if that information was covered in a design review or informal discussions, and said he believed it was common knowledge that the feather locks were required in the transonic region. Other Scaled Composites and Virgin Galactic pilots stated they were also aware of the hazards associated with the unlocking the feather early during boost. Multiple pilots stated that they never considered that a pilot would unlock the feather prior to 1.40 Mach during a boost flight. The accident pilot could not recall the discussion of unlocking the feather in the transonic region being hazardous or catastrophic. The pilot stated that he and other pilots were aware that the locks were required to be locked in the transonic regime. He knew that if the feather locks were not locked it could be hazardous or catastrophic, but did not remember them discussing it in analysis.[115]

The SS2 POH, page 165 stated the following:

> *At 1.4 Mach the feather should be unlocked and if both hooks do not unlock the boost must immediately be aborted.*

The SS2 POH, page 103 further stated:

> *WARNING*

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based on hinge moments. He said dealing with the redundancies was complex. For more information, see Human Factors Group Chairman's Factual Report.

113 For further information on risk mitigations, see Systems Safety Group Chairman's Factual Report.

114 For the former Scaled Composites Chief Aerodynamicist interview, see Human Performance Group Chairman's Factual Report.

115 See Attachment 1 – Interview Summaries.

Although the feather locks are cycled during normal preflight and prerelease checks, inadvertently actuating the feather will likely result in catastrophic failure of the mated pair.

The SS2 Emergency Procedures (Feather Locks Fail to Close), page 83, contained conditions that should not be exceeded if the feather locks were not locked:

If BOTH feather locks are not LOCKED
1. Maintain <2.5g ≤ 0.8M & <10° α if >0.8M

The SS2 Emergency Procedures (Feather Down Reentry), page 88, stated:

A sudden feather up >200 KEAS will likely be catastrophic.

The NTSB reviewed the SS2 Pilot Operating Handbook, the SS2 Normal Procedures and the SS2 Emergency Procedures, and could not find a caution or warning that stated unlocking the feather prior to 1.40 Mach could be catastrophic. According to interviews with Scaled test pilots, Virgin Galactic Test Pilots, Scaled Composites Project and Flight Test Engineers, and FAA personnel who observed Scaled Composites simulator training, no one could recall seeing any SS2 pilot unlock the feather prior to 1.40 Mach during a training event. A review of the notes and data taken from the integrated simulations leading up to PF04 found no documentation of an early unlocking of the feather prior to 1.40 Mach.

13.3.1 Feather Unlock Timing

According to preliminary cockpit video data, the release from the WK2 occurred at 17:07:19.27 when the cockpit image vibrated, indicating the motion of release. At 17:07:26.83, the PFD indicated a transition from ADC to INS (0.80 Mach). At 17:07:26.91, the co-pilot made a “Mach point eight” callout, and at 17:07:28.39 made an “unlocking” callout. At 17:07:28.90, the Feather Lock Handles reached the full unlock position. Based on the preliminary cockpit video data:

- Release to the 0.80 Mach callout was 7.64 seconds.
- Release to the feather unlock action was 9.63 seconds.

On November 4, 2014 the Operations and Human Performance Group Chairmen participated in a simulator test conducted in the Scaled Composites SS2 simulator.[116] Multiple simulated PF04 runs were made to document the timing from launch to both the 0.80 Mach and 1.40 Mach callouts. According to the simulator runs:

- Release to the 0.80 Mach callout ranged from 8.18 to 10.59 seconds.
- Release to the 1.40 Mach callout ranged from 24.66 to 25.23 seconds.

[116] The test runs were made with the SS2 pilots from PF03. For further information, see Attachment 10 – Simulator Test Plan.

14.0 Ground Station

The Ground Station (control room) for PF04 was located at the Scaled Composites facilities at KMHV airport. The room was staffed with Scaled Composites and Virgin Galactic engineers and FAA observers during the PF04 launch operations.

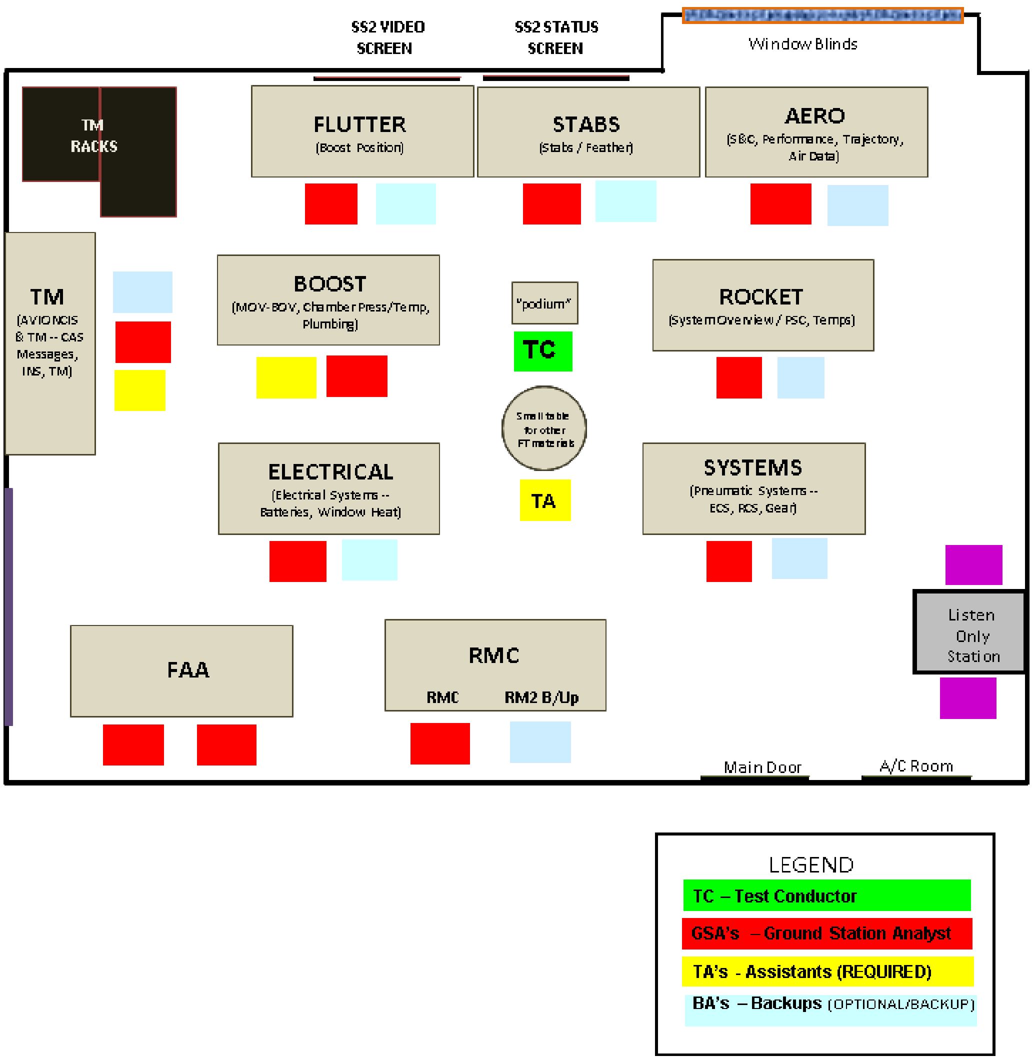

Figure 11: Ground Station physical layout.[117]

According to Scaled Composites, while the Pilot in Command (PIC) was ultimately responsible for the conduct of the test and had authority over all decisions related to the test, the Test Conductor (TC) was in the Ground Station to support the PIC and flight crew in an advisory role. Supporting the TC were the Ground Station Analysts (GSA) and the Technical Assistants (TA).[118] The TC's roles and responsibilities were defined in the Scaled Composites T1B-90E059

[117] Source: Scaled Composites Mission Control 2012 (2012-11-30) Rev A.
[118] Source: Scaled Composites T1B-90E059 Tier1B Ground Station Operating Guidelines.

Tier1B Ground Station Operating Guidelines. Mission guidelines, plans, and checklists for the TC were found in the M339 SpaceShipTwo Mission Notebook.

The TC for PF04 was a test pilot from Virgin Galactic, and PF04 was his first time to act as TC on a powered flight.[119] Assisting the TC was the Test Assistant (TA), who was the Scaled Composites Test Pilot who flew SS2 on PF01, PF02, and was the SS2 Instructor Pilot on PF03.

GSAs and the TC monitored multiple communications loops within the ground station: the airborne loops, and the ground loops. The TC listened and talked on both the Com 2 and the TC loops and listened on the cockpit loop. Normally the GSAs were only allowed to talk on the ground loops and listen on both, but could transmit if necessary on the airborne loops.

The airborne loops were:

- Cockpit loop (hot mic from the cockpit)
- COM1 loop (Radio 1)
- COM2 loop (Radio 2)

The ground loops included:

- Console loop (monitored by all GSAs for background discussions that do not need to involve the TC).
- TC loop (monitored by all GSAs). TC was hot mic-enabled on this line. This was the primary communications loop to share flight information.
- Rocket Loop: monitored for all propulsion stations. This let the propulsion engineers communicate with each other without interrupting other communications.
- Phone 1 loop and Phone 2 loop: allowed outside communications via a telephone link. During launches the the phone 1 loop was connected to the Edwards AFB Flight Test Center where a program engineer was stationed to provide real-time information from long-range optics to the test team.

These loops not only kept the TC informed about the normal and abnormal behavior of the vehicle, but they also kept the rest of the team informed. When a GSA informed the TC about an anomaly, they were also informing the rest of the team. The loops also allowed each team member to be aware of the current workload, and wait for an appropriate time to interject. The loops also allowed the GSAs to anticipate a question before it occurred, and provide the relevant answer in a timely manner.[120]

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[119] According to his interview, the TC's previous experience included 23 years in the Air Force flying fighters, and the last 14 years were in flight test. He estimated his total flying time at 8,800 hours, with 7,500 hours as PIC. His test flight experience was in the F-16 experimental and classified aircraft. He spent two years as the Chief of Safety for a developmental flight test organization. Prior to that he spent a year as Chief of Safety for Edwards and Eglin AFB. His most recent job prior to VG was as operations group commander.

[120] Source: M339 SpaceShipTwo Mission Notebook, Section 4.0 Communication Flow.

According to the Scaled Composites experimental permit, (Section 3.7 Tracking and Communication), a transponder was installed on the SS2 vehicle in order to provide real-time position and velocity to Air Traffic Control during aircraft (i.e., captive or glide phase of flight) operations. In addition, the vehicle transmitted telemetry data to the Ground Station, which included position, velocity, and attitude information. The Ground Station also computed and displayed the IIP. The Ground Station had the capability to maintain two-way communication with Air Traffic Control from take-off to landing. The SS2 and WK2 communications system consisted of two communications transceiver radios in SS2 and three in WK2 used for two-way communication between the flight crews, ATC, and the Scaled Composites Ground Station.

The Ground Station included tracking antennas to support telemetry and VHF communications. It had the capability of monitoring SS2 on-board cockpit and boom video and real time continuous audio (hot mic). The data was distributed to ten ground stations at which the GSA's could perform real-time analysis and help support the flight. The TC acted as the Ground Station lead and the single point of contact with the flight crew.

While the Ground Station had the capabilities of monitoring the telemetry from the SS2 and maintaining communications with both vehicles, it did not have remote operator capabilities for the SS2 or WK2.[121]

15.0 FAA Oversight[122]

The Office of Commercial Space Transportation (AST) was established in 1984 as part of the Office of the Secretary of Transportation within the Department of Transportation (DOT). In November 1995, AST was transferred to the Federal Aviation Administration (FAA) as the FAA's only space-related line of business. According to the FAA, AST was established to:

- Regulate the U.S. commercial space transportation industry, to ensure compliance with international obligations of the United States, and to protect the public health and safety, safety of property, and national security and foreign policy interests of the United States;
- Encourage, facilitate, and promote commercial space launches and reentries by the private sector;
- Recommend appropriate changes in Federal statutes, treaties, regulations, policies, plans, and procedures; and
- Facilitate the strengthening and expansion of the United States space transportation infrastructure.

15.1 AST Organization

According to the FAA, AST managed its licensing and regulatory work as well as a variety of programs and initiatives to ensure the health and facilitate the growth of the U.S. commercial space transportation industry through the Office of the Associate Administrator. The divisions of

[121] According to 14 CFR 401.5 Definitions, "remote operator" meant a crew member who (1) had the ability to control, in real time, a launch or reentry vehicle's flight path, and (2) was not on board the controlled vehicle.
[122] Source: http://www.faa.gov/about/office_org/headquarters_offices/ast/about/

AST included: the Licensing and Evaluation Division, the Regulations and Analysis Division, the Safety Inspection Division, and the Operations Integration Division.

The AST issued FAA licenses and experimental permits for commercial launches of orbital rockets and suborbital rockets. The first U.S. licensed launch was a suborbital launch of a Starfire vehicle on March 29, 1989. Since then, AST had licensed over 230 launches. The AST also issued licenses for the operations of non-federal launch sites, or "commercial spaceports." Since 1996, AST has issued site operator licenses for eight commercial spaceports.

Scaled Composites and Virgin Galactic provided AST with quarterly briefings on SS2 and WK2 program updates. According to records provided to the NTSB, those updates began on January 20, 2011, and the most recent update prior to PF04 occurred on August 13, 2014. The quarterly meeting updates generally reviewed program milestones since the previous meeting, rocket motor and systems updates, experimental permit progress, and future scheduled activities.

15.2 AST Divisions[123]

15.2.1 AST 200 Licensing & Evaluation Division

The Licensing and Evaluation Division, formerly the Licensing and Safety Division, carried out AST's responsibility to ensure public health and safety by licensing commercial space launches and re-entries, licensing the operation of non-federal launch sites, and determining insurance or other financial responsibility requirements for commercial launch activities. This division also issued experimental permits for developmental reusable suborbital rockets and safety approvals for launch vehicles, reentry vehicles, safety systems, processes, services, and/or components for commercial launch operations and personnel performing functions related to licensed/permitted launch activities.[124]

The Licensing and Evaluation Division reviewed and approved license applications, developed license terms and conditions, and, when necessary, evaluated requests for waivers of regulatory provisions. The components of the licensing process included: pre-licensing consultation, policy review, payload review, safety evaluation, financial responsibility determination, and environmental review.

According to the AST 200 Manager of Licensing and Evaluation, after an application for an experimental permit was accepted, the AST 200 division took the lead in evaluating the permit. AST 200 management would then assign a Project Team Lead to manage the evaluation of the permit application, which included AST 200 analysts (flight safety and system safety analysts), AST 300 (Regulations & Analysis Division) evaluators, and AST 100 (Space Transportation Development Division) inspectors, as part of the project team.

According to interviews, during the experimental permit evaluation period, any AST 200 evaluator's questions specifically for Scaled Composites were reviewed by the AST 200 management, the permit team lead and the AST chief engineer prior to being sent to AST 500

[123] For additional information on the FAA AST, see the Systems Safety Group Chairman's Factual Report.

[124] Source: http://www.faa.gov/about/office_org/headquarters_offices/ast/about/licensing_evaluation_division.

(Operations Integration Division of AST) for presentation to Scaled Composites. According to the Deputy Division Manager of AST 500, questions from AST 200 evaluators were reviewed to determine their relevance to public safety. [125]

Scaled Composites did not request the waiver of FAA regulations published in the Federal Register Volume 78 number 138 Thursday, July 18, 2013, and according to the AST Project Team Lead, the drafting of the FAA waiver originated within AST 200 and AST 300. The waiver was eventually signed off by the AST Chief Engineer and FAA General Counsel before being published in the Federal Register. Further, according to interviews, Scaled Composites had no role in the waiver and, according to the SS2 Flight Test Project Engineer, was not aware of the waiver until late June 2013.[126]

15.2.2 AST 300 Regulations and Analysis Division[127]

The Regulations and Analysis Division, formerly the Systems Engineering and Training Division, developed, managed, and executed the AST Rulemaking Program and the AST Tools and Analysis Program. Under the Tools and Analysis Program, AST 300 analysts conducted flight safety analyses, system safety analyses, and specific types of hazard and risk analyses. The two technical teams within AST 300 were the system safety team and the flight safety analysis team.

According to interviews, during the experimental permit application period, questions from AST 300 analysts while evaluating the Scaled Composites experimental permit application were reviewed by AST 300 management, the AST 200 permit team lead, and the chief engineer prior to being presented to AST 500 (Operations Integration Division of AST) for presentation to Scaled Composites. According to interviews with AST 500 personnel, questions from AST 300 analysts were reviewed to determine their relevance to public safety.

For the Hazard Analysis Waiver, the Deputy of AST 300 stated his division sent AST 200 a memo outlining the requirements of 14 CFR 437.55, and according to the Project Team Lead, the origins of the waiver came from within AST 200 and AST 300. He further said it was not unusual for the FAA to draft and issue a waiver for an applicant who did not request a waiver "because we've had other applicants do the same thing where they've applied for a license or permit, they think they met a requirement, we disagreed. And so the way we handle that is we consider that [a permit] submittal that doesn't meet the requirement as tantamount to applying for a waiver."[128]

15.2.3 AST 500 Operations Integration Division

The Operations Integration Division was established in 2012 for the coordination and oversight of operations, programs and initiatives taking place in AST field offices. AST field offices included the Commercial Space Transportation Safety Office at Patrick Air Force Base, Florida,

[125] See Attachment 2 – Interview Transcripts.
[126] See Attachment 1 – Interview Summaries.
[127] Source: http://www.faa.gov/about/office_org/headquarters_offices/ast/about/regulation_analysis_division.
[128] See Attachment 2 – Interview Transcripts.

the West Coast Operations Office in California, and the AST Commercial Resupply Services Office in Houston, Texas.[129]

According to interviews, in an effort to reduce the burden on an applicant such as Scaled Composites from having to interface with multiple AST divisions during a project, AST identified an individual from AST 500 to be the main point of contact with Scaled Composites throughout the lifecycle of the SS2 project. That individual's role was to interface with Scaled Composites, build a relationship, and facilitate communication between Scaled Composites and AST. In 2012, AST created the AST 500 Operations Integration Division for the primary purpose of building relationships, facilitating communication and conducting pre-application consultations with applicants. Because AST 500 was located in California close to Mojave, they did the day-to-day interfacing with Scaled Composites.

According to interviews, the Deputy of AST 500 primarily communicated with the project team lead from AST 200 and did not have regular direct interaction with the personnel working in the other AST divisions. Questions for Scaled Composites from those other divisions would first be submitted to the AST 200 permit team lead, which were reviewed by AST management and the chief engineer prior to being sent to the AST 500 point of contact and then to Scaled Composites.

If someone on the project team, which included AST 200 and AST 300 personnel, needed to have a technical interchange meeting (TIM) with Scaled Composites, the AST 500 point of contact would set that up. That individual did not have direct interaction with AST 300, and all information and questions to an applicant received from AST evaluators was sent to the AST 200 project team lead so AST management could ensure the questions were "clear and relevant to public safety."[130]

15.2.4 AST 400 Safety Inspection Division[131]

The AST safety inspection function, previously implemented under the former Licensing and Safety Division, was established as a separate division in March 2011 for the continued purpose of executing AST's Compliance and Enforcement program. Safety inspection involved the monitoring of all FAA-licensed, permitted, and otherwise regulated commercial space transportation activities to ensure compliance with FAA regulations and to provide for the protection of public safety and the safety of public property. Because the FAA licensed and permitted commercial space transportation operations and not vehicles, safety inspection correspondingly involved the monitoring of those public safety related pre-operational, operational and post-operational activities.

The Safety Inspection Division managed the AST Compliance & Enforcement Program, AST Mishap Response Program, AST Standardization & Evaluation (Stan/Eval) Program, and the AST Safety Inspector Training Program. The Division developed and implemented safety inspection procedures and guides and directed the safety inspector training program for the

[129] Source: http://www.faa.gov/about/office_org/headquarters_offices/ast/about/operations_integration_division.
[130] See Attachment 1 – Interview Summaries.
[131] Source: http://www.faa.gov/about/office_org/headquarters_offices/ast/about/safety_inspection_division/.

training, certification, and credentialing of FAA Commercial Space Transportation Safety Inspectors.

The Safety Inspection Division included a Headquarters component and three field office locations (Vandenberg AFB, CA; Patrick AFB, FL; and Wallops Flight Facility, VA).

According to AST, the operator was responsible for complying with the regulations and the provisions outlined in the experimental permit, and AST 400 inspectors were to ensure compliance with the regulations and the permit.

15.2.4.1 Compliance & Enforcement Program

AST safety inspectors monitored those pre-operational, operational and post operational phases of FAA regulated commercial space transportation activities which could impact public safety and the safety of property.

Pre-operational activities included the qualification, installation, and testing of flight safety system components; mission readiness reviews; safety compliance and support reviews, safety working groups, and planning discussions; and operational rehearsals, simulations, and exercises. Operational activities included monitoring countdown procedures; operator communication processes; procedural execution; vehicle processing and preparation; safety critical operator/launch site personnel interaction; and identifying non-nominal or public safety issues. Post operational activities included the monitoring of post operational reviews; post flight/reentry evaluations; lessons learned discussions; documenting observed compliance and non-compliance; and communicating and coordinating with operators to correct noncompliance issues.

The Division Manager administered the safety inspection process while the Enforcement Program Manager ensured proper development and maintenance of the Enforcement Program including adherence with all applicable FAA Orders and AST internal procedures.

15.2.4.2 Mishap Response Program[132]

The Mishap Response Program was AST's interface for all mishap related activities. These activities included: mishap response and accident investigation plan reviews in support of AST license and permit evaluations; interaction with the licensee or permittee for mishap preparation and prevention; coordination and mishap response planning with FAA partners and stakeholders; development, review, and updates to AST mishap checklists; management of post-mishap activities within AST including distribution of mishap failure analyses and corrective action information for review and resolution through the Mishap Review Board.

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[132] As previously mentioned, according to 14 Code of Federal Regulations (CFR) 401.5 Definitions, “Mishap” was defined as a launch or reentry accident, launch or reentry incident, launch site accident, failure to complete a launch or reentry as planned, or an unplanned event or series of events resulting in a fatality or serious injury (as defined in 49 CFR 830.2), or resulting in greater than $25,000 worth of damage to a payload, a launch or reentry vehicle, a launch or reentry support facility or government property located on the launch or reentry site.

The Mishap Response Program was also the external interface for mishap coordination and response planning to the United States Air Force (USAF) federal ranges, National Aeronautics and Space Administration (NASA), National Transportation Safety Board (NTSB), FAA Washington Operations Center (WOC), and FAA Office of Accident Investigation and Prevention (AVP).

The Mishap Response Coordinator (MRC) was the primary office of responsibility for developing, maintaining, and executing the AST Mishap Response Program.

15.2.4.3 Standardization & Evaluation (Stan/Eval) Program

The Standardization & Evaluation (Stan/Eval) Program evaluated the effectiveness of the AST safety inspection program as it pertained to the safety inspection mission and individual safety inspector duties.

The Stan/Eval program was to ensure that AST uniformly and consistently executed the provisions of United States statutes, FAA regulations, the Division's internal procedures, and related training and support supplements developed and implemented as part of the AST Safety Inspection Division.

Stan/Eval was the primary office of responsibility for reviewing, evaluating, and maintaining all AST Safety Inspection Division internal procedures and related standardized inspection forms, templates, and documentation. The office evaluated safety inspector qualifications and recommended safety inspector candidates for certification; evaluated the performance of all safety inspectors to ensure consistent application and execution of inspection procedures and practices; monitored safety inspector proficiency and certification status; developed, scheduled, and implemented all safety inspector training exercises; scheduled all inspection assignment tasks; identified program trends and procedural inconsistencies; evaluated subject matter expertise and equivalency; performed written evaluations of training exercises, subject matter expertise, and prior safety inspector candidate experience equivalency. The Stan/Eval Officer administered the program and ensured frontline compliance with program objectives and protection of AST resources.

15.3 Safety Inspection Program

14 CFR 437.93 Compliance Monitoring, stated:

> *A permittee must allow access by, and cooperate with, federal officers or employees or other individuals authorized by the FAA to observe any activities of the permittee, or of its contractors or subcontractors, associated with the conduct of permitted activities.*

The FAA AST 400 division had 11 designated safety inspectors called Commercial Space Transportation Safety Inspectors (CSTSI). CSTSI's were credentialed according to the guidance defined in FAA Order 8800.1A (dated April 7, 2014),[133] and were responsible for inspections of AST permitted and licensed commercial space activities.

[133] See Attachment 18 – FAA Order 8800.1A.

AST internally developed a Safety Inspection Plan to review experimental permit activities, and utilized this plan as a checklist for inspection of a permittee prior to a permitted launch. The safety inspection was to verify compliance with:

1) 51 U.S.C. Title 51, Subtitle V (Commercial Space Launch Act),
2) 14 C.F.R. Chapter III (Regulations),
3) 14 C.F.R. Chapter I (Regulations), and
4) Terms and Conditions of the experimental permit including representations made in license application.

The Safety Inspection Plan could include pre- and post-flight ground operations, hardware installation, integration and test, verifying safety documentation, including crew qualification and training, informed consent, and waiver of claim records, policies, and procedures; and monitoring of prelaunch meetings, mission dress rehearsals, launch operations, and post-launch meetings, etc. The Safety Inspection Plan contained inspection items that assisted the CSTSI during permitted launch and reentry activities, and began as a generic spread sheet that was then tailored for each particular inspection activity.

The primary focus of the FAA's Safety Inspection Plan for Scaled Composites was to observe the SS2 launch and recovery operations, ensure compliance with experimental permit No. EP-12-007 and its terms and conditions, and verify continued accuracy of representations contained in the experimental permit application.

According to interviews with the CSTSI's that conducted safety inspections on Scaled Composites prior to powered flight activities, although there was a 14 CFR 437.93 requirement for Scaled Composites to make themselves available for inspection, there was no requirement for the FAA/AST to conduct any inspection of a permittee. A CSTSI's primary role was to ensure an applicant was compliant with the regulations and their experimental permit. Though they could communicate any concerns they had to their point of contact at Scaled Composites, CSTSI's did not have the ability to make a "go/no-go" call for a launch if they observed a compliance or regulatory violation.

According to the FAA, CSTSI's conducted the following pre-launch safety inspections on Scaled Composites prior to the PF04 launch:

October 17, 2014 – Integrated simulator session
October 27, 2014 – Integrated simulator session
October 29, 2014 – Pilot record inspection
October 29, 2014 – Maintenance record inspection
October 31, 2014 – Permitted launch operations

The NTSB reviewed the results of the Safety Inspection Plans conducted on Scaled Composites prior to PF01, PF02, PF03 and PF04. The PF02 and PF03 Safety Inspection Plans (dated July 16, 2013 and November 11, 2013 respectively) included the following language:

Non-Compliances

The following pre-approved non-compliances (waivers, equivalent levels of safety) are associated with this safety inspection:

1) Waiver of 14 CFR 437.29 and 437.55(a)

The FAA waiver of 14 CFR 437.29 and 437.55(a) was dated July 18, 2013. A review of the results of the PF04 Safety Inspection Plan did not include language that the Scaled Composites non-compliance with 14 CFR 437.29 and 437.55(a) was associated with the PF04 inspection.

F. LIST OF ATTACHMENTS

Attachment 1: Interview Summaries
Attachment 2: Interview Transcripts
Attachment 3: Party Forms
Attachment 4: Control Room Statements
Attachment 5: IFE Witness Statements
Attachment 6: Witness Statements
Attachment 7: Ground Training Syllabus
Attachment 8: WK2 Training Syllabus
Attachment 9: Extra Training Syllabus
Attachment 10: SS2 Simulator Test Plan
Attachment 11: Pilot Ground Training
Attachment 12: Pilot SS2 Training
Attachment 13: Pilot WK2 Training
Attachment 14: SS2 Simulator Logs
Attachment 15: Powered and Glide Flight Assignments
Attachment 16: Airport and Airspace Information
Attachment 17: FAA AST Organizational Chart
Attachment 18: FAA Order 8800.1A
Attachment 19: Scaled Organizational Charts
Attachment 20: SS2 Operating Limitations
Attachment 21: Scaled Test Pilot Assignment Description
Attachment 22: FAA Mojave Airport Environmental Assessment
Attachment 23: WK2 Pilot Information
Attachment 24: Flight and Test Reviews
Attachment 25: FAA Responses

Submitted by:

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