Attachment 1

to the Human Performance Group Chairman's Factual Report

DCA15MA019

Interview Summaries

Interview: Jim Tighe, Chief Aerodynamicist, Zee Aero

Date: November 5, 2014
Location: Scaled Composites; Mojave, CA
Time: 0915 PST
Present: Human Performance Group: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA); Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites; Operations Group: David Lawrence – NTSB; David Gerlach – FAA; David Mackay – Virgin Galactic; Mark Stucky – Scaled Composites
Representative: Gary Halbert, Counsel, Holland & Knight

During the interview, Mr. Tighe stated the following:

His full name was James Joseph Tighe and he was 39 years old. He currently worked for Zee Aero as a chief aerodynamicist and previously held the same titled position at Scaled Composites. At Scaled Composites, his roles and responsibilities included the Tier1B program and the original configuration development of the vehicles. He was responsible as the project engineer for most of the build phase, led the flight test group and was the test conductor for powered flights (PF) 01-03. He reported to Matt Stinemetze. He worked at Scaled for 14 years and although he left the company on October 9, 2014, he continued to work for them as a consultant. His previous job duties at Scaled were absorbed by multiple people after he left.

He was a pilot but was not actively flying; he flew Cessna airplanes. He graduated from University of Colorado with a B.S. in Aerospace Engineering. He previously worked at Boeing on commercial airplanes for 4 years in their aerospace group and was then hired by Scaled Composites. He had no educational experience in human factors, but had professional experience. He was not sure if anyone on his team had formal human factors training.

Asked what kind of human factors standards/evaluation/protocols his team relied on in the development of SpaceShipTwo, he said it was an experimental aircraft and they used standards as guidelines. He was not specifically involved with designing the ergonomics aspects such as reach. It was a consideration and during the development pilots were heavily involved in the placement and layout of the cockpit. Pilots sat in seat mockups. It was a team effort with respect to who would be using the vehicle. It also helped that while they were not human factors experts, they were pilots so they knew what mattered or not. It worked well around there. They got pilots input early on. For example, Clint Nichols recognized that the seat headrest was an issue and he made it better. He was proud that they were not a human factors organization but it was the pilots and engineers that made a vehicle that worked really well.

Regarding ergonomics aspects of the cockpit, it was the pilots who laid the cockpit out. The original layout was done by Terry Agold . Later, the Virgin Galactic guys made really good improvements to the panel. Matt Stinemetze designed the handle for the feather lock and actuators. Pete Siebold, Clint Nichols, and Mike Alsbury were involved. Cory Bird also did a lot of mock ups for seat layout. Mr. Tighe was involved in the window placement and looked at line of sight, eyepoint, and where the pilot needed to look at very specific phases of flight.

He did not recall if any outside agencies with human factors expertise were consulted during the design.

Asked if there were any human factors issues identified during testing, he said there was a lot of work making sure that the breakout force on the locks, feather and ball valves were reasonable. A lot of testing was done by Scaled Composites and more recently by Virgin Galactic. Some good improvements were made to the panels in response to concerns by Virgin Galactic pilots, and as the vehicle design evolved. The rocket motor design in particular had changed, so the pilot interface had to change with that. Part of the changes were to keep up with the changing systems.

From the design perspective, he was the project engineer during fabrication of the feather system. Aaron Cassebeer did the detailed design and Matt Stinemetze did the pilot interface. Mr. Tighe was involved in how the cabling and ball valves worked, and was also involved in the system safety aspect of the layout. There was an original fault tree analysis of all the systems. One failure hazard identified was a failure of the feather to extend. He worked with them to develop the feather unlock procedure. Pilots would unlock the feather during the boost so they had a chance to abort the flight and avoid a feather-down reentry. He said the procedure was "unfortunately my idea." The logic was if one of the locks failed then the pilots could not open the other lock because of the interconnect. So from a fault tree perspective there were gates. If the system did not work when either one of the locks failed, it was not a very reliable system, so by unlocking the feather early the crew could abort the flight in time and successfully save the vehicle.

Mach 1.4 was established as the speed to unlock that gave a sufficient margin of safety. He thought at Mach 1.1 or maybe even lower, there was a down force on the tail. From Mach 0.8 to 1.0 was about where the uplift was on the tail and then it switched to a download.

Safeguards in place to prevent an inadvertent unlock of the feather was the handle itself. A pilot had to move the handle to the right out of the detent in order to move it. The handle also required quite a bit of force. The pilot would have to know he was moving the handle. It was a physical mitigation in that the pilot had to know it was occurring. Procedurally, it was in the normal procedures and also on the flight card. From a crew resource management standpoint, it was a balance between the pilot and copilot communications. They wanted to unlock the feather in a sufficient timeline, so there was sufficient time to respond if the feather did not unlock. The copilot unlock of the feather at Mach 1.4 was not in response to a command from the pilot. That was thought as a good compromise by having it be accomplished at the appropriate time. There was a balance of workload going on. It was hard to convey. When under those g forces and the short time available, things happened fast. A pilot could not look at everything which was why the vehicle was designed for a two-person crew; due to the high stress workload environment and each pilot had to do things in parallel. There was a division of labor. The division of labor was practiced so they did not unlock early. From what he saw in the simulator sessions, he thought the procedure worked "amazingly well."

Pilots were made aware of speed at which to unlock the feather formally through the normal procedures and also informally. They were a small team. He was not sure if there was an official document that showed the tail load that was given to the pilots.

During the flight readiness review (FRR), they showed the tail forces as a function of time, but he did not think he specifically gave pilots that document. Mach 1.2 was the number he thought they needed to unlock the feather safely and using Mach 1.4 added in a margin. He felt confident in these numbers. He tried to make it as clear as he could. He was not aware of a time when a pilot unlocked the feather early in the simulator, but he was not a part of all the simulator sessions leading up to the PF04 event.

The procedure was ultimately written by Mark Stucky, but it was a collaborative effort between the flight test community and himself; they all worked on the procedures. They provided feedback outside the simulator and provided "what if" scenarios. He thought it was a collaborative effort to develop the procedures. A pilot-induced early unlocking of the feather system was not considered as a 'what if' that he was aware of.

He was the test conductor on PF01-3. During PF01, the pilot did not unlock the feather. In PF02 and 3, the feather was unlocked during the boost. He thought the unlock occurred shortly after burnout on PF02 and just before burnout on PF03. He thought that occurred around Mach 1.5. The feather was coincidental around the burnout. The vehicle went to near vertical and feathered and recovered. He did not recall when the unlock was in relation to Mach 1.4. He did not recall what the procedure on the test card was, but thought it was around the end of the burnout which would have been around Mach 1.4. Feather unlock was "definitely after the pull up."

The gate to avoid inadvertent unlock was best described as a detent. This was designed by Aaron Cassebeer. He was not aware of any consideration of other mitigating factors to prevent early unlocking of the system. He did not want to say that they treated pilots like they were infallible, but the mitigation was more for a failure of the feather system to unlock and not pilot error.

As the test conductor he was involved in the integrated system. He never witnessed an early unlocking or feathering by the pilots.

He generated all aerodynamic tables used in the simulator. He also contributed other small things unrelated to this. He was not aware of any simulator data to model the flight characteristics of early unlocking of the feather and subsequent feathering. They modeled system failures, but this was not one of them.

He wrote the stab actuator section in the POH. He did not recall anything in the POH referencing the transonic issues with unlocking the feather between Mach 0.8 and 1.0.

A key consideration was being able to land the airplane. During the boost, pilots were looking at the displays. During the approach, high key and low key, they wanted to maximize the time the pilot could see the end of the runway and the planned touchdown point. That was the general philosophy that looked at the compromise between the weight of the window and visibility. An obscuration plot was generated that showed the value of the windows with different sizes and in different locations. There was an advisory circular (AC) for window placement, but the windows in this vehicle did not meet those guidelines. Maximum performance of a spaceship was predicated on being as light as possible, but windows were heavy. Pilot seat position was also taken into consideration. They wanted to keep the pressure vessel circular in shape and light in weight.

For configuration of the seat position, the goal was to move the head as close to the window as possible while allowing sufficient clearance so the pilot could move around and not strike his head in the event of an accident. The other thing considered was keeping the pressure vessel circular and minimizing weight. Like any design, it was a compromise.

The general layout was based around the nitrous tank which was 90 inches in diameter. They wanted to place the crew as close as they could in the 90 inch diameter circle. The windows were laid out around that. Head placement in the vessel came first then the center console to make sure pilots could reach it. The consideration was if they made the center console too close that the pilots could not egress. The other compromise was to design the center console in SpaceShipTwo such that it closely resembled the throttle quadrant on the WhiteKnightTwo since pilots flew in both vehicles. Matt Stinemetze came up with the original design. The handles were designed such that the feather had to be unlocked before it could be extended. The unlock was an actuation that the pilot had to pull down and the other required the pilot to pull it out. The pilot had to unlock first then actuate the feather; this design was very intentional on his part.

The cockpit was symmetric so he thought line of sight to the feather operating system was the same for both pilots.

With respect to boost, the loads analysis was a part of it and they looked at a variety of failure conditions. One output of that analysis was the moments. A key consideration was that the load on the feather system was a download on the tail. Mach 1.2 was safe to unlock the feathers and it was padded to Mach 1.4. They also wanted to allow for a reasonable reaction time for the pilots should the feathers not unlock and the flight needs to be aborted and successfully recover the vehicle. They used a 3 second reaction time which was “kind of a standard.” There were no regulations or other AC for suborbital spaceships, so they applied other rules and 3 seconds was consistent with engine out reaction time. They also worked with the pilots and the pilots agreed on the reaction time. The approximate time from release to ignition was about 2-3 seconds and from ignition to Mach 1.5 was about 18-19 seconds, so approximately 20-21 seconds from release. Pilot workload during this time was “extreme” so division of labor and CRM was so important. That was also why the vehicle had two crewmembers.

The unlock of the feather at Mach 1.4 was on the flight test card, because there was no time or space for the pilot to hold or refer to the normal procedure checklist. It was spelled out on the flight card for the pilot and the crew tasks.

The setup of the control room was an evolution from the SpaceShipOne days. There were similar stations, but different roles. Mike Alsbury was heavily involved in that for SpaceShipOne. For SpaceShipTwo, Brian Binnie was involved and then Mr. Tighe took over near the start of the SpaceShipTwo powered flights. The biggest change was including the rocket motor team. He liked the division of duties that Mr. Binnie had set up. In the control room there were two large plasma TVs hanging on the wall that provided a general overall awareness. On the left screen were video streams and rocket motor status. On the right screen was SpaceShipTwo specific information like cabin altitude, vehicle attitude, temperature, a moving map display and a caution advisory. The various responsible engineers sat around the room. In the first row from left to right was the flutter station, then the stab station which looked at trim surfaces and feather, the aerodynamic station that looked at trajectory, aerodynamics, and stability; in row 2 was the telemetry station that looked at avionics health, then Mr. Tighe, who at the time was the test conductor, then the rocket motor station; in row 3 was the electrical station, the test conductor assistant who helped coordinate activities with external parties in an emergency and helped manage the room, then the system station; in row 4 was the rocket motor controller (RMC) team. All communications went through the test conductor who filtered the information and pared it down to specific direct instructions or responses in the most timely manner to the pilot. The pilot was in charge of the test, not the test conductor. The ground station team was there to act as an advisor to help make the right decisions. As a part of Mr. Tighe's advisory role as the previous test conductor, he looked at the aircraft throughout the testing to make sure it was within limits. There were certain checkpoints such as prior to takeoff, climbing through 40,000 feet and prior to release.

The feather on SpaceShipOne was controlled on the left console and there were a series of levers that would unlock and raise the feather. He said that was about 14 years ago and did not remember all the details. It did not have any other safety features. SpaceShipOne lacked a feather handle split which was added to SpaceShipTwo. Even if a ball valve got locked up, the knob could be unscrewed and it would release. After burnout, the pilot would unlock the feather on SpaceShipOne. He did not remember the test conductor's actions during that phase. There was no analysis done as to whether SpaceShipOne could do a feather-down reentry. The conjecture was that it could, but he never did the analysis. He doubted it would be able to survive.

He did not know if SpaceShipTwo could survive a feather-down reentry. Per the analysis, there was a margin of safety of 1.0, so there was no structural safety margin for some components. But there was still a pretty good chance, but it was difficult to say. There was a lot to consider like structural failure, flutter, thermal issues, pilot handling quality issues, 10-g loads down, high g loads eyeballs-out, and it was a high workload task. All procedures had some risk and a feather down reentry had the highest risk which was why they had the mitigation of unlocking the feather early. He did an analysis and on paper it was survivable. It was difficult to say what the threshold was where they could not survive. With a 40 second burn duration, the safety margin was 1.5, but between a 40-60 second burn, it was less than 1.5 safety margin on the structure; these were rough numbers.

He did not know the g loads to keep the feather down without running the numbers.

The loads on the tail were driven by aerodynamic balancing. As more gs were pulled, a larger balancing load was needed. As the aircraft approached supersonic speed, the shock wave would set up an area of suction, so that balance had to be kept. Once the shock wave moved back the center of pressure would move. He thought there was a download force on the tail starting between Mach 1.0 and 1.1. The highest uploads on the tail would be between 0.8 and 1.0 Mach. That was when the tail wanted to feather.

During PF02 they flew an envelope expansion flight, but maintained a reasonable AOA (angle of attack). They went through the gamma turn prior to motor shutdown. When they slowed through that range they saw the feather crack a little bit, but they knew it would happen and they were okay with it because of the dynamic pressure. If the aircraft was at Mach 0.8 and 60,000 feet, the forces were less than at lower altitudes and the feather could be unlocked safely because of the dynamic pressure.

They were always looking to expand the envelope and they gradually expanded it in terms of altitude, dynamic pressure, AOA and g. PF02 allowed them to expand the alpha Mach envelope.

He did not recall any q limits for feather extension. Intentional feather q limit was (b) (4) [redacted] knots for feather transition. Normally on feather glide flights, the aircraft was slowed to almost stall and then they deployed feather for minimal risk.

The Q alpha curve was not that simple. The fin was not fixed and can be moved, so the loads came out of the trajectory. The loads could not be simplified to dynamic pressure versus angle of attack. He could not figure out a way to tabulate the loads.

He ran hundreds of trajectories to understand the tail loads then picked worst one and used that for the structural limitations. The feather assembly weighs about (b) (4) [redacted] pounds (b) (4) [redacted].

There was a normal set of procedures established to minimize pilot technique. Stabilizer was set at -9.0 until Mach 1.0 and then it was moved to -14.0 to capture the pitch up. This procedure was done the same for all the flight crews. Specific trim schedule was rigorously followed to help minimize the variability.

Much of the original design work was done by Mr. Tighe. Virgin Galactic established a space act agreement with NASA Ames who did some independent aerodynamic modeling. Some initial testing was done just prior to PF01 which was consistent with modeling done early on. They flew PF01 and it was close to the predicted behavior. One thing that was different than expected was in the transonic flight regime, the pitch bobble on the predicted model (seen in the simulator) was not as pronounced as the real aircraft. He added another model to accurately represent the pitch up seen during the flight.

Prior to PF03, there was modeling of blister wing tanks. There was talk of adding (b) (4) [redacted] and where to put it. The safest thing was to not put it in the cabin in the event of a leak, so they thought to put it in the wing, but it would not fit without adding “blisters” on the top and bottom of the wing to make room for the additional tank on each wing. He modeled it with and without blisters and settled on an area where the wing blister tank did not have any aerodynamic effect. There was no change in effect on the feathers. PF04 was not the first flight with the blisters.

The control room would know if a pilot unlocked the feather at the wrong time by looking at the big board in the top center where the feather status indication was. There were two "L"s that indicated the feather was unlocked and they could also tell by the status of the pressure system. If they unlocked early, the pressure switches would change and the micro switches would be in the unlock position. The test conductor also had 2 MFDs that showed the same information that the pilots saw. During the accident flight, the test conductor's displays were showing the PFD on one display and the trim screen which included feather status on the other display. He thought it was about 10 seconds between release and Mach 1.0 so there was no time to look at all data. When he was test conductor, he tried to focus on the safety critical things, such as that the release of the aircraft was stable, there was a good plume, on energy, and AOA. He could not look at everything which was why there were all of the other people in the room. The test conductor was not focused on Mach and timing of the feather unlock; a different station was monitoring this. CRM to him meant there was division of labor and reliance on the team to do their tasks. There was a specific mission script and people provided feedback in his ears. A part of the script was a "Mach 1 on energy" call.

If the stab station saw the pilot unlock the feather early, the engineer could make a direct call to the crew or to the test conductor depending on what their abort criteria was for communicating directly to the crew. There were clear communication criteria so the comms did not get overloaded. If it was something ambiguous, the engineer would make the call to the test conductor and then the test conductor would call the crew. If it was something that necessitated calling off the boost, the engineer would call "knock it off" to the crew.

If in the simulator and the pilot unlocked the feather early, it would be a debrief item. The simulator operator was a test pilot. They would execute the flight card and emergency procedures and then there would be a discussion afterwards. The crew, test conductor and engineers would discuss what they saw. There were no sidebar discussions.

Asked if it would be beneficial to add another check before unlocking the feather, he said yes, but it was difficult. There were ways to improve it, but more research was needed of premature feather unlock. It would be worth revisiting the loads at all phases of flight. They would also need to determine if they could move the unlocking to later in the event and still balance the risk of reentry. With the burn time, it may be unreasonable to assume they would reach Mach 1.4 in a 6 second burn time. There was feedback from the pressure switch to let them know the load on the feather system. There may be some more obvious feedback that could be incorporated that into an "ok to unlock" light. Pitch attitude would not be a good crosscheck[1]; they could use burn time, pitch attitude, maybe not g, maybe strain on the locks, maybe an MFD ok to unlock light. In the simulator, they could look at all these parameters; but in an actual event, there was a much smaller focus and ability to process multiple data sources was not as good.[2] He said this was from hindsight.[3]

[1] In a Scaled Composites letter dated May 7, 2015, Mr. Tighe provided the following clarification to his interview summary: It would not be a good crosscheck to rely on pitch attitude, however, because it is not a reliable source of tail load.

[2] In a Scaled Composites letter dated May 7, 2015, Mr. Tighe provided the following clarification to his interview summary: A pilot's ability to process multiple data sources was not as good.

[3] In a Scaled Composites letter dated May 7, 2015, Mr. Tighe provided the following clarification to his interview summary: Other mitigations worth investigating include investigating the hazard of feather down entry with the

He was not aware of a time delay from data in the vehicle to the control room. They did a comm check and time check and checked on the big board to make sure the time was consistent. They also looked at crew actions and made sure those were consistent with the procedure. The crew would make sure the feather unlock worked twice before release. The feather unlock was done over the hot mic and time hacks were done over the radio. Some data sources had lags, for example, in PF02 the off vehicle ground video had a delay, but they were aware of that before the test.

The test conductor was responsible for the time lag, but all engineers looked at their parameters. He was not sure if this was done for PF04, but he remembered the time hack occurring over the radio. He did check the time lag himself for PF04.

When the copilot unlocked the feather early during the accident flight, the control room action that should have happened was a "knock it off" call, which was called but later. This call could have been done 1-2 seconds prior on PF04, but it may or may not have changed the outcome of the departure of the vehicle.

The pilot was in control of the test, but the test conductor gave the 'green' for takeoff and climb. There was no confusion that would cause a pilot to go past the point of a control room clearance and execute a test without control room concurrence.

After the accident he tried to think if there was another cue presented to the copilot that he would have thought was a reading of Mach 1.4. He did not have a specific answer, but thought it would be good to run through the simulator to look at all of the parameters and see if there was something that confused the copilot. At Mach 0.8, he thought the Nz would have been 3-4 so the copilot was probably not looking at that. He was not aware of anything that could be misconstrued as Mach. It was not obvious to him as to what could have been misread.

Pilots had been testing realistic scenarios with the feather controls for about 7 years and he thought the procedure to unlock the feather at Mach 1.4 had been done since the beginning. It was a change from the procedure in SpaceShipOne. In the fault tree analysis, there was always the concern that the feather would jam and that would prevent the unlock from happening.

They talked to the pilots about the unlock procedure and they got "buy in" from the pilots.

In the control room on the day of the accident, he remembered a nuisance issue prior to takeoff with the DAU1 reading the PSC status indication. It was a status bit that came back to avionics. The crew pushed the circuit breaker in and should go from unpowered to standby, but it momentarily flickered to unpowered again. The engineer said it was functioning nominally based on other control room data. There was a risk of scrubbing the mission on the ramp and the appropriate decision was made to continue with the flight test. There was a nuisance indication that the left stab screen plot was off by a half degree. The winds were a concern, but they were

---

assumption that the feathers did not unlock; investigating mechanical interlocks that prevent early feather unlocks; and reviewing the nature of communications between the flight and ground crew. These mitigations require careful consideration, however, and may independently present further safety issues of their own.

within the limits through the release. He looked at everything he could and verified that everything was within limits even though that was not his duty.

His current role at Scaled Composites was in an advisory capacity. Mr. Stucky was the test conductor assistant and Todd Ericson was the test conductor. Mr. Tighe's role was to sit quietly unless he saw something outside the limits.

Pertaining to the accident, what he saw was that the SpaceShipTwo dropped, the motor lit, he looked briefly and the AOA was nominal, attitude of the vehicle was wings level and it was roughly under control. He heard 0.8, and saw the vehicle pitched up which he thought was about 80 degrees nose up and he saw 14 alpha (AOA). There was no roll evident so it was probably not a structural failure. He did not look at the locks.

In his current role for Scaled Composites, he was on the phone for the flight readiness review and he provided some continuity between the previous flights and PF04. He was also available to them by phone about the tools he developed the day prior to the accident flight to support meetings like the maintenance and ER review, and the flight card briefing. He said the final responsibility for the sign off was the board itself that was made up of team members.

He recalled some mention of the mechanical properties of the nylon fuel grain and that the surface temperature needed to be correct and within limits.

He had an indirect role in the design of the PFD. He was involved in the SpaceShipOne avionics display and SpaceShipTwo was evolutionary from that. The SpaceShipTwo PFD was reflective of the engineer that that developed that. There was a compromise with clutter and not overloading pilots. The addition of the trim display to the PFD was done after he left (Oct. 9th), but they did have that information on SpaceShipOne and it was useful.

Workload during the boost was a reasonable thing that a pilot can be expected to execute. Avionics did a lot of health monitoring for the pilots. A lot of work was put into the division of labor between the pilots and the avionics dependence to give the pilots the right information. A lot of work was done to make it an achievable task.

In terms of design requirements, the intent was for SpaceShipTwo to be a two crew aircraft. There was some notion of a paying copilot, but the engineers did not entertain that as a possibility.

The PF04 script was a spreadsheet with color coding for each person – pilots, what was to be said over comms, what was happening in the control room. The expectation was that they would try to say the same thing every time, but failures could affect this. He knew what the script was, because he wrote it for PF01-3 with input from others. He reviewed the PF04 script and the changes made sense. He could not comment on whether they were done in the simulator, but guesses they probably were. The script was in the flight test notebook and in the flight test folder.

He was proud of the SpaceShipTwo project and proud of Mike Alsbury who was the first pilot in the right seat on the first powered flight.

The interview ended at 1115.

Interview: Mark Stucky, Engineering Test Pilot, Scaled Composites

Date: November 5, 2014
Location: Scaled Composites; Mojave, CA
Time: 1140 PST
Present: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA); Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites
Representative: Gary Halbert, Counsel, Holland & Knight

During the interview, Mr. Stucky stated the following:

His full name was Mark Stucky. He worked for Scaled Composites and his title was Engineering Test Pilot. He was hired by Scaled Composites about April 2009.

He took over the aircraft documentation from Brian Binnie. Mr. Binnie had started the POH, and normal and emergency procedures. He became involved a few months after being hired and then took a more active role in those publications with an emphasis on WhiteKnightTwo. As SpaceShipTwo got closer to flying, he took over those documentations too as they became more mature. He was the responsible engineer for them and provided input to Mr. Binnie. He tried to translate the documents into “pilotese” and to make them more robust. He vetted them through other flight crews and systems experts; it was an iterative process.

He did not follow any standards in the development of the documents. They were already in a format when he took over, and his experience working for different government agencies taught him there was not any one format to follow. He tried to focus on the content.

He did not have a formal human factors background, but had a reputation for being good at human factors as an operator since the early 1980s. He developed this reputation in his role as a pilot assigned to operational development, and worked on dozens of software changes for the F-18 that incorporated human factors elements.

The SpaceShipTwo POH was originally geared towards glide flights when the rocket motor was still being developed, with an emphasis on normal and emergency procedures. The initial concern for glide flight was how to get the feather in the down position and not the up position. As the program matured, the procedures were more carefully considered for powered flight. The initial feather flights in the glide phase focused on how to get the feather down, not how to get it up. It was more important to get it up during powered flight. The feather unlock procedure for glide flight was simpler since powered flight was not taken into consideration. There was a desire to have the same set of feather unlock procedures for both glide flight and powered flight. The SpaceShipTwo documentations were scheduled to be turned over the Virgin Galactic.

Mr. Stucky was asked about the procedural consistencies between WhiteKnightTwo and SpaceShipTwo. The development of the “modern” procedures for both aircraft was accomplished by Mr. Stucky and he felt there was consistency. Virgin Galactic took over the WhiteKnightTwo procedures; however, Scaled Composites was still involved and provided concurrence to WhiteKnightTwo procedural changes made by Virgin Galactic. Both companies worked closely together to develop those procedures. Mr. Stucky did not recall any procedural changes made by Virgin Galactic that he did not agree with. The procedure development process for SpaceShipTwo had started prior to Mr. Stucky being hired in 2009. Scaled Composites used to approve any procedural changes but he did not think they did that currently.

Mr. Stucky was a pilot for both WhiteKnightTwo and SpaceShipTwo. There was not a lot of "relearning" or degradation of procedures when switching between the two aircraft. The decision to land on the runway centerline or offset from the runway centerline was one of the biggest differences between flying the two aircraft for him. Most of his flying experience was in WhiteKnightTwo and it was the core foundation of his early experiences at Scaled Composites.

There were enough simulation flights in the SpaceShipTwo simulator that established a good foundation for actual flights. The simulator events varied in the number of participants. Some simulation events involved only the pilot and copilot while other simulation events involved the entire crew that was involved during an actual flight including the control room. All of the simulation events were formal and extremely structured and were treated as a real mission. The first simulation scenario of the day in the SpaceShipTwo simulator usually started at the L-10 checks prior to releasing SpaceShipTwo from WhiteKnightTwo. The subsequent scenarios started 1 minute prior to release to save time. The flight test card was followed "to a T" throughout all the simulator scenarios. Some crews asked for a nominal scenario, without failures or emergencies, if they had not flown in the aircraft for a while on the first simulator run of the day. Abnormals were typically inserted into the simulator scenarios; some required the crew to go off the test card to deal with that particular failure scenario or emergency, and other allowed the full test card to be run. It was important to go into the SpaceShipTwo simulator the day prior to an actual SpaceShipTwo flight to practice the nominal flight profile.

The accident crew invited Mr. Stucky to observe their simulator sessions the day before the accident. He observed a few runs but the re-run of the PF03 data was scheduled in the control room around the same time the pilots were in the simulator, so he was not able to witness the entire simulator session. After the re-run of PF03 was complete, Mr. Stucky was surprised to see the crew still in the simulator running scenarios but he did not stick around. He witnessed the crew conduct multiple scenarios of the PF04 profile from SpaceShipTwo release to feather before resetting the simulator back to prior to release. He did not witness the accident crew conduct any simulator scenarios during the landing phase of flight on that day. Mr. Stucky had the impression that "practice makes more than perfect" and the runs were "overkill." The accident crew was wearing headsets in the simulator, so he was unable to hear all of what they were saying to each other. Pete Siebold seemed driven to continue the simulations.

He saw the crew performing nominal simulator sessions between 0800 and 1000 on October 30. They then had the maintenance and ER briefing which started at 1030 and was scheduled until noon. After that, they did the comm checks at the FAITH hanger where the flight crew got into their respective vehicles and did the radio checks. He did not recall if he saw the accident crew after that.

On October 27, the crew had a simulator session from 0730 until 0930 followed by the Delta FRR for PF04 until noon. October 28 was the final PF04 card review from 0730 until 1230, then

Mr. Stucky and Mr. Alsbury went to the control room for an oral at the stab station. Mr. Stucky and Mr. Alsbury left for a trip on October 28 and returned in the late afternoon of October 29. The next event was the nominal simulator session set up by Mr. Siebold on October 30. Mr. Alsbury did not express any concerns about PF04 to Mr. Stucky during that time. The accident crew looked great the morning of the accident and he first saw them at the delta briefing that morning.

The PF04 test card was developed by the accident crew. The only procedural change for PF04 was to unlock feather under boost per the normal procedures; this procedure had the crew accomplish this task earlier on the previous two flights. This was also the first time the crew had time to wait before unlocking the feather and they changed the card to reflect that. Mr. Siebold came up with his own cadence for this phase of flight. The idea behind the cards the crew used during flight was to have items that were not covered in the normal procedures but that were important for that particular mission. It was difficult to reference multiple procedures simultaneously during a short period of time, so the card was developed to be used as the primary reference. The important steps were put on the card and were written in a way that helped ensure the cadence of the steps taken by the crew continued properly. The steps were not numbered, but they were written in such a way that indicated the flow between pilot flying and pilot monitoring actions.

Mr. Stucky had previously flown with Mr. Siebold and Mr. Alsbury. They were both professional and took their jobs very seriously. Both pilots were interested in crew resource management (CRM). Mr. Stucky felt that he brought more CRM to Scaled Composites than was present prior to his arrival at the company. It helped with the standardization of callouts. Virgin Galactic pilots tended to have pilots with airline experience, space shuttle experience and/or multi-crew experience than Scaled Composites pilots. The Virgin Galactic pilots helped come up with standard callouts between pilot flying and pilot monitoring as well as more standardization for the briefings. They wanted it to be standardized so any crew could fly together. This was really driving with WhiteKnightTwo but they tried to continue it into SpaceShipTwo. A level of standardization was required by the experimental authorization checkout process.

PF04 as well as the last few glide flights were not as familiar as the first three powered flights to Mr. Stucky since he was on the “periphery” of these flights. Mr. Stucky was not as aware of the discussions leading up to PF04 and whether there was any discussions regarding a cross check or verification between pilot flying and pilot monitoring of the Mach 1.4 feather unlock call and associated action. Many pilots “chair fly” the flight profile prior to the flight to mentally prepare for the powered flight. Mr. Stucky had experienced catapult shots off of aircraft carriers so he was used to it, but for others there was always a bit of surprise with the difference in sensory feeling.

He had no issues viewing the displays during powered flight. References were used to help determine what size fonts could be read during different g loads and the vibration shake table was used to determine acceptable vibration levels. The rocket motor controller (RMC) abort criteria took this into account. He thought there was a good ability to read all of the displays during the boost phase of powered flights. It was not sensory overload, but a “waterfall.” There was a lot of information for the pilot to process in a short amount of time during powered flight, so the pilot had to focus appropriately and time share for the best situation awareness of what was happening in the aircraft. He characterized the workload as demanding, but not extreme, which when complete, gave a test pilot great satisfaction in having done well.

There was no pressure to unlock the feather before the FEATHER LOCKS CAS message appeared but it was “standard pilot ego.” He recalled that during a backup simulator session he got distracted and got the nuisance feather lock CAS message that embarrassed him. He never heard Mr. Siebold or Mr. Alsbury talk about not wanting to get the CAS message.

The primary flight display (PFD) had already been developed prior to his arrival at Scaled Composites. The PFD was an “excellent” display and there was no reason for him to try to change anything. He had input and wanted changes on other displays that were not as mature. On the PFD, he had slight concerns regarding the depiction of the sky pointer and ground pointer. This was backwards from other aircraft he had flown and occasionally gave him negative training during small bank angle turns.

He was very involved and started the concept for the energy display on the MFD, including how it was presented to the pilots. He had small inputs on other displays to make them better before they were finalized.

He was not sure of the decision making for the new trim display on the PFD. It was incorporated into the simulator without his knowledge and he was surprised when he saw it in the SpaceShipTwo simulator; however, he was not as involved with the discussion for PF04. He thought the new trim indications on the PFD were a good idea.

He was asked, using the benefit of hindsight, if there was anything the crew could have misconstrued as being 1.4 Mach. He said the pilot decision to unlock feather should have been based on Mach 1.4 but he would like to know what data was showing on the PFD and the g level at the time the feathers were unlocked during the accident flight. On his previous flights, the pilot monitoring made the Mach 0.8 aural call which prepared him, as the pilot flying, for the upcoming transonic phase of flight as well as the pitch up associated with this phase. This also helped the pilot flying remember not to fight the pitch up during the transonic phase. After the pitch up occurred, there was a pitch down and that was the time for the pilot to start trimming the aircraft; the flight would be at about 0.94 Mach after the pitch up. That took approximately 5 seconds and the aircraft speed would probably be around 1.2 Mach. The copilot’s next duty should be to focus back on Mach, but he did not know how Mr. Siebold briefed it or did it. Mr. Stucky would have the pilot monitoring automatically unlock feather by announcing the action with time enough for him to disagree and stop the action if need be.

Mr. Stucky had flown SpaceShipTwo from the left and right seats. The unlock feather lever could be seen by him from both seats, but he mentioned the pilot flying could be “channelized” enough to visually miss this action.

He did not see the accident crew prior to the briefing the morning of the accident because he was over with the vehicles. He figured the crew would be checking weather and other relevant tasks.

Mr. Stucky was not aware of Mr. Alsbury having any recent flight experience that would cause negative training, from a displays perspective, from one aircraft to another.

The checklist for SpaceShipTwo likely started off similar to other Scaled Composite checklists, however, both the SpaceShipTwo and WhiteKnightTwo checklists developed into a much more sophisticated format than previous aircraft. Similarly, the flight test cards were also much better than previous program flight test cards. Mr. Alsbury would be used to seeing the checklists and test card in the format used for the accident flight.

Mr. Stucky flew with Mr. Alsbury during PF01. Mr. Alsbury was in the right seat and performed pilot monitoring duties during that flight. Mr. Stucky said that Mr. Alsbury knew what to expect from watching SpaceShipOne videos. The simulator for SpaceShipTwo had enough fidelity to be helpful as good preparation for the actual flights. PF01 was much more dynamic and had a higher workload than PF04. It was not on the flight test card, but they talked about what things aerodynamically would make Mr. Stucky call for an abort. He did not include the control room in those briefs.

Mr. Stucky provided academic training for Test Conductor Todd Ericson. There were two formal sessions that lasted “multiple” hours each as well as a couple of informal sessions after that.

Asked if there were any secondary checks before unlocking the feather, he said it was obvious that the process broke down and there were things they could do better. There were no simulation events that he was aware of, that incorporated a catastrophic event like early unlocking of the feather. There was not likely any action the accident crew could have taken after the feather unlock lever was moved to be able to recover from that action. That mistake should never be made. This was not something a crew can rely on the control room to prevent. He hoped they would have such good flows in the future to prevent this from happening again. He stated that the copilot should not have to say “unlocking” as he was unlocking.

He considered the PFDs in SpaceShipTwo as the best PFD he had used, but that did not mean he would not change it slightly. The Mach indication was adequate, but was not normally a critical parameter. The Nz display was also adequate and was also not typically a critical parameter. He found that it was really what the pilot was used to. If a pilot was used to digital displays, he would think a digital display was best, but if a pilot was used to analog displays, he would like that better. He thought their integration of both digital and analog display information, and trend bars, was good.

He did not recall a pilot ever misreading the Mach display on the PFD or any other parameter on the display. He was also not aware of a pilot misusing the feather unlock during a simulator session or flight.

Mr. Stucky was not aware of any discussions regarding the trim indications being added to the PFD and the change was not communicated to him. He first thought, that maybe as the backup crew for PF04, that the change was not required to be communicated to them, but it became clear to Mr. Stucky that Mr. Siebold was also not aware of this change. He had no memory of that happening before. He always felt changes were discussed amongst the pilots and agreed upon before changes were incorporated into the simulator. He thought the project pilot should be involved in the review process before all changes were incorporated into the simulator. He expected pilots to be a part of the process and for it to not be done in a vacuum; it did not have to be all pilots but some pilots should be involved.

Mr. Alsbury did not mention any concerns to him about PF04 when they were traveling together the week of the accident flight. They were working on another project and those on the other project were more concerned that Mr. Alsbury would have enough time to prepare for PF04 so they sent them home from their trip on October 29, which was earlier than planned; this offended Mr. Alsbury. Mr. Alsbury felt that they could judge themselves and determine whether they were fit for the flight.

He could not think of any other parameters that a pilot could misread as Mach.

He thought Dave Mackay was the only pilot who was concerned about the feather unlock handle being similar to throttles in another type aircraft.

Mr. Stucky was asked if there was anything else he would like to add to the interview. He did not want the pilot flying to focus on the Mach number during the boost phase of flight. He thought it was more important for the pilot flying to look for things like aircraft pitch excursions or other aircraft control issues. They had to pick and choose the workload appropriately for the crew. If each pilot tried to do the other pilot's job, it would detract them. He hoped the NTSB would look at survivability issues and the force required to activate the emergency O2 systems, whether Mr. Alsbury attempted to activate his oxygen, and also how to preflight the O2 system.

Mr. Stucky clarified that he felt Mr. Alsbury jumped a paragraph ahead on the flight test card not a few seconds ahead.

The interview ended at 1250.

Interview: Peter Kalogiannis, Project Engineer Avionics, Scaled Composites

Date: November 5, 2014
Location: Scaled Composites; Mojave, CA
Time: 1300 PST
Present: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA); Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites
Representative: Bob Carter,[4] Counsel, Holland & Knight

During the interview, Mr. Kalogiannis stated the following:

His full name was Peter Kalogiannis. He was a project engineer avionics at Scaled Composites and had been in that position for 7.5 years. He was hired by Scaled Composites about 8.5 years ago as an avionics design engineer.

When Pete Siebold was promoted to Flight Director, Mr. Kalogiannis took over his role. His responsibilities included the flight display design process. This included the aircraft, simulator, and telemetry (TM) system.

He was involved from the inception of the SpaceShipTwo displays which evolved conceptually from the SpaceShipOne avionics and expanded to a two person cockpit concept. The SpaceShipTwo displays were a blend of the SpaceShipOne displays, the guidance and map especially. The new displays were developed in house for the SpaceShipTwo in conjunction with the pilots and his personal recommendations. Some outside work was used in the development of the counter pointers (altitude and airspeed) based on a paper on limitations of tape-based displays for high workload and high g environments. He also used several FAA advisory circulars (AC) for reference but he did not verify compliance. He did not recall which references were used but would provide a list.

Mr. Kalogiannis had no formal human factors background. His background was in avionics development. He was a commercial, multi-engine rated pilot and had flown as a copilot on WhiteKnightTwo on several occasions and had one flight as a copilot on SpaceShipTwo for a captive carry mated flight. No one on the avionics display team had human factors experience and no outside experts were consulted. The design and implementation was a collaborative effort especially with Peter Siebold who had an avionics development background and SpaceShipOne experience. High level avionic architecture was developed primarily through collaboration, discussion, and prototyping. ACs were referenced for detailed design work; for example, like when to trigger a cabin pressure warning. The initial design display was a collaborative effort with pilots, especially with Pete Siebold who had an avionics background. They discussed what the system would be like and what the major elements would be. His discussion with Pete Siebold was primarily prototype development rather than referencing ACs. There was an ACs for when they should trigger a cabin pressure warning. It was a collaboration for top level things.

[4] For the first part of the interview, Mr. Kalogiannis was represented by Gary Halbert, Counsel, Holland & Knight.

The display of Mach number was in the same location as SpaceShipOne since it was similar to SpaceShipOne purpose. He did not recall a discussion on font size or the use of any reference for determining size of the Mach font. They did make a change in the Mach display going from 2 digits past the decimal to 3 digits past the decimal based on a request from a pilot, he thought from Pete Siebold, for certain test points on WhiteKnightTwo. Pete wanted the added decimal to better determine the rates of Mach number change.

The WhiteKnightTwo, SpaceShipTwo, and simulator PFD were very similar in design. He did not recall any developmental discussion on the use of colors on the PFD. White was used for font color on the PFDs with no color schemes on PFD labels. Value colors changed on limits. Color design approach on system type displays aligned with cautions and warnings. Label versus value color differentiation did not apply.

Vibration testing was conducted to determine readability of displays under simulated boost conditions. The team mounted a crew seat and display on a vibration table to determine maximum acceptable level of vibration acceptable for display readability. They made qualitative decisions based on this testing to determine at what point displays were illegible. They used the frequency spectrum that corresponded with the rocket motor vibration levels. This helped them determine what the maximum levels were. This testing was done for SpaceShipTwo, but he was not sure if it was done for SpaceShipOne.

Pitch and Roll trim indications were recently added to the PFD based on a request from multiple pilots including Mark Stucky and a Virgin Galactic pilot. This request was logged in to the avionics change request software system, JIRA. There were several design iterations with the first design being a graphical representation. He was not happy with the size and location of the display and the amount of space it took up on the display. They then rolled back to a simple textual trim display to meet the software qualification time line. He had not received feedback from pilots on the trim display. He recalled that before the trim display modification to the PFD was implemented it was shown to a Virgin Galactic pilot, Dave Mackay but he did not know to what level any pilots were involved in the implementation.

The main portion of the avionics architecture had been stable for some time (menu system, method of interface, bezel controls, PFD (sans trim), and Map display). Most changes made were in response to a pilot request. Initially when there were only one or two pilots on the project it was straight forward to keep the pilots informed of avionics changes. When more pilots came on the project, the process for changes went through Mark Stucky. They would place any new changes in the simulator first for evaluation. Pilots would be briefed at the simulator pre-brief on any changes prior to the sessions. Once the design was accepted, the information was put into the Pilot Operating Handbook (POH) by Mark Stucky. There were recent changes to the (b) (4)

The display avionics team used the software JIRA to track issues with the avionics system. This included pilot requests, bugs, and testing anomalies. JIRA was maintained by Scaled Composites and everyone could make inputs. It was a web-based interface used primarily by the avionics team. Pilots could and occasionally would input issues, but typically he would get inputs verbally or by email. These came after simulator sessions or by the flight test engineer or Jim Tighe would generate inputs. The main portion of the avionics system, the menu or main interface for the pilots, had been stable for some time. The exception was the addition of the trim setting to the PFD.

There were no specific high g discussions during development but during the vibration testing they considered access, control movement and button depression. They did not see a need for pilots to move knobs or access displays during boost, re-entry, or high g portions of the flights.

When asked where a pilot would look to make a feather unlock decision he stated that the Mach was on one portion of the PFD and trim was on two portions; the original center MFD trim strip and on the top half of the PFD/ADI. He did not recall any misreading of those displays in the simulator or on multiple WhiteKnightTwo flights and his one SpaceShipTwo flight.

He did not know how he was chosen to fly on any particular sortie other than Pete Siebold asked him several days prior to a particular flight if he wanted to fly. This occurred around flight 20. It was the same process for SpaceShipTwo.

The Virgin Galactic/The Spaceship Company engineers also had access to JIRA. It was his understanding that pilots would contact the avionics engineer who would then enter the issue into JIRA. Just prior to PF04 the integration focus had been on the MFD modifications required for (b) (4) (95% of avionic engineer workload) versus the additional trim PFD modifications (5% of avionic engineer workload). The process did not involve formal feedback on the system and the avionics team relied solely on the crew's willingness to provide feedback on the avionics displays.

Scaled Composites did not have a Cockpit Working Group. Any avionic modifications did not have a formal feedback system. The team would look for the crews to provide any feedback if they had an issue with the displays. If a pilot made the input of an issue to JIRA then the pilot would be the "reporter" of that issue and would get updates on the progress; others would also receive updates on its progress, including himself. Those emails could include status updates such as "open", "in work" or "implemented". Each issue would be evaluated and a decision made, and based on priority it would be included in the upcoming build. All commits on code base would be attached to JIRA issues that allowed them to be tracked.

JIRA was an off-the-shelf software package for issue tracking that was usually found in software type environments but was adaptive for engineering processes.

The PFD top half had no difference between the simulator and the SpaceShipTwo regarding hardware and software. WhiteKnightTwo was the same except there were no pitch and roll trim indications on the WhiteKnightTwo PFD. Other WhiteKnightTwo differences included the air data defaults. In WhiteKnightTwo the source defaulted to air data computer (ADC) and in the SpaceShipTwo it defaulted to AUTO mode. There were no differences in the airspeed or Mach indications between WhiteKnightTwo and SS2. He was not sure if there were any differences on the Nz indication.

He reemphasized that no MFD manipulation was required during boost and that the displays were still readable up to rocket motor analysis vibration levels.

He had seen the flight crew in the brief the morning of the flight but did not speak with them. He did not see anything out of the ordinary. On the day before the accident flight, during the communication checks, he would have seen them on the cockpit video. He also saw the flight crew stop by the control room the morning of the flight during the launch delay before the rocket motor pressurization. He did not know if they ran any simulations that morning in the simulator. Earlier in the week he would have seen them in the normal briefs leading up to the flight, but again did not recall anything out of the normal.

Every issue in JIRA was given a priority of either grounding, critical, major, minor, or trivial. Usually the reporter would set the priority when entering the issue into the system. Anyone had the ability to change the priority as the issue progressed through the process, but usually only the reporter or he would change it. Sometimes pilots would go into the system and change the priority after explaining their concerns. Grounding was not safe for flight. Critical affected safety of flight. Major prevented the conduct of the mission or flight test, but was not related to vehicle safety. He could not recall what minor was, but it was less than major and trivial was usually something very small.

He could not recall how long the trim PFD modification was in the simulator prior to flight, but was sure there were multiple simulator sessions with the trim display on the PFD prior to PF04.

The interview ended at 1350.

Interview: Cory Bird, Vice President, Scaled Composites

Date: November 5, 2014
Location: Scaled Composites; Mojave, CA
Time: 1355 PST
Present: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA); Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites
Representative: Bob Carter, Counsel, Holland & Knight

During the interview, Mr. Bird stated the following:

His full name was Cory Richard Bird and he was 56 years old. He was Vice President/General Manager at Scaled Composites and had been in that position for about 2 years. He had been with the company for about 29 years and held various positions including program manager, project engineer and shop lead. He was a private pilot, was not a test pilot, but had flown some chase pilot duties early on in his Scaled Composites career.

His duties and responsibilities included backing up the company president. Ultimately with regards to safety, he was delegated with test readiness and flight readiness and also took care of programs from the technical side. He was the board chair for both the technical review boards and flight readiness review board. He was the chief engineer on a major program and project manager on WhiteKnightOne. He also spent his time on any issues from the technical side.

PF04 was planned to have more than a 20 second burn. He had been heavily involved in the rocket motor for about a year and helped to resolve the rocket motor issue as it was their highest priority. The motor on SpaceShipTwo was strong. His other function was to chair the flight readiness review (FRR). As a part of the FRR, he got the board together and sat through presentations from all systems groups. WhiteKnightTwo had been flying for 6 years and SpaceShipTwo had been flying for 4 years. The propulsion system was a big issue. Because the vehicles had been flying for several years, he called the FRR the Delta FRR. Actions were generated from the FRR and they would work on those. PF04 was originally scheduled for October 23, but all of the items were not completed so PF04 was rescheduled for October 31.

He did not attend the briefing on the day of the flight.

The FRR involved a risk assessment. He expected the responsible parties to come to the FRR with a good briefing. He assembled the team within Scaled Composites and brought some rocket experts from the outside. They would go through the presentations and encouraged everyone to ask questions, not just the subject matter experts. The action items were documented, and when the meeting was over they started working on those items.

Following the first FRR meeting on October 3, 2014, there were some late breaking loads that needed additional analysis to ensure they had the correct margins. They postponed the flight and got healthy numbers for the structure.

The first PF04 FRR was on October 3 and the main issue was incorporating the (b) (4) The next meeting, the Delta FRR, was on October 27.

The full risk assessment was done a long time ago when they started flying the vehicle. The risk assessment was to consider a (b) (4) leak and what would happen. They talked about the venting and the gloves to go around the valves. They did a lot of testing on the operating temperature of the valves. The risk assessment concentrated on the change to the propulsion system and that was the focus on PF04 flight.

When they did something completely new they would do a risk assessment. In this particular instance, the procedures were very clear from the previous risk assessments.

Issues were documented in an Excel spreadsheet. “Instigators” were the guys who asked the question and their names were also documented in the spreadsheet. Also documented was the resolution. The project engineer or program manager started filling them up and they got archived with the attendee list. The project engineer or program manager, for PF04 it was Matt Stinemetze, was running the show and was responsible for archiving that data.

There were no issues discussed at the FRR about the feather unlock. The previous week slip caused a “town hall” meeting to be generated to see what else they could be missing. While they were down for another week, George Whitesides, CEO of Virgin Galactic asked him, “What else are we missing?” So, on the Tuesday before the accident flight they had what he called a “town hall” meeting. They did not turn on any computers and rather discussed how they could predict things they did not know about. Attendees included Virgin Galactic and Scaled Composites personnel. The purpose was to think about things they had not thought about before. It was a productive meeting and lasted about 4 hours. They talked about the feather locks “quite a bit”. He asked why they unlocked the feathers and it was explained to him. He was told that once they got to Mach 1.4 they had about 5 seconds to unlock the feathers. If the feathers did not unlock, they could abort the flight and recover the vehicle. They never imagined that the feather system would be unlocked too soon. It was same procedure on the Tier 1 program. Pete Siebold was at the “town hall” meeting, but Mike Alsbury was not. He tried to get one person from each discipline to attend. The feather system was just one topic out of many. They also discussed the reaction control system (RCS). Unlocking the feather system too soon was not discussed and the issue of when to unlock was not reiterated in that meeting.

He believed pilots were aware of when to unlock the feather system, because that was how they did it in the simulator. There were 12 simulator session runs from September 22 until the day before the accident that ran the PF04 test card. He did not know if the accident crew participated in those simulator sessions, but he assumed they did to some extent. The requirement was to have at least three simulator sessions at a minimum within a couple of weeks before a test flight. He commented that he had never seen so many simulator sessions prior to a flight previously.

The accident crew attended the FRR meetings. About 40 action items resulted from the first FRR meeting. The big issues were the trajectories, because the loads had gone up slightly and also the (b) (4) . The other items were nominal.

Regarding the trajectory issues, there was a new motor on the vehicle, so little things changed the trajectory. For example, the motor was slightly shorter which created a slightly different center of gravity. Jim Tighe had developed the trajectories. The load limits generated from the trajectories were once in a lifetime events. They liked to fly up to about 80% of the limit. For the PF04 event, they thought they were at about 70% of the limit. Some of the late breaking analysis showed they may have been 13-15% higher, so some load cases did not meet the 80% requirement.

For PF events 1-3, the motor had more performance and the weight was a little different so the tail loads were different. They needed to go study this and concluded that to give them more margin, they would not do a 1.5 factor of safety. They said they had to meet a 1.9 factor of safety and that was what they did.

The "town hall" meeting was just dreamt up. He thought every FRR should be like that, but as the FRR got bigger, it was harder to do that. They sometimes liked to go offsite for the FRR meeting. Nothing came out of the town hall meet that would have prevented the accident, but it was a good forum to discuss items. He made the list of which Scaled Composites personnel would attend the meeting.

He was sure the 1.4 Mach was documented somewhere. It was a limitation in the flight card. Pete Siebold was the director of flight operations.

He thought others would see the safety culture at Scaled Composites as a model. There was no one else in the industry doing it quite like they were. Everyone was a system safety person; there was not one safety guy. When they designed the system, they knew that "no single point failure will kill a pilot."

No one liked the FRR process, because that was the day they had to defend their product. The problem with the "defend" culture in the industry is as soon as a person said their product was safe, they could not change that, because they already said it was okay.

He was asked to clarify his statement about no single point failure killing a pilot. He said they could not do anything about a pilot who at 10 or 20 feet before landing pushed the nose over. Pilot error was really difficult. He had not seen any video and had not been in the simulator since the accident, so he did not know if the protocol was broken. He used the example of another one step process, stating "why would a pilot decompress the cabin at 50,000 feet?" It was a one step process, but a pilot would not do that.

There were no human factors people involved in the organization, but they had former military people that could "talk the talk." He was not sure of any discussion about bringing a human factors expert in. When working the rocket motor, the human factors consideration was that he wondered if a pilot could survive a particular event. They took pilots and put them on a vibrator and they did actions while there were vibrations.[5] He said they paid a lot of attention to the environment, pressurization and ergonomics issues.

---

[5] In a Scaled Composites letter dated May 7, 2015, Mr. Bird provided the following clarification to his interview summary: To test the pilot's ability to withstand these vibrations, Scaled placed pilots on a vibrating table and asked

He did not think there was any pressure from Virgin Galactic to perform PF04. Scaled Composites had a desire to please the customer, but he thought the fact that they delayed the flight due to unresolved issues showed that their system safety worked. But they obviously wanted to get back in the air as quickly as possible.

He was asked how they knew they were looking at the right ergonomics and human factors issues. [6] He said they had a history of building things and relied typically on their pilots. They did not have a separate test flight group, but rather their pilots that gave input were the pilots that were going to fly the vehicle. The experience level of pilots was "pretty deep." They kept most of that stuff internal. They were a research company and would change things up to see if it worked. They were never going to learn if they followed the MIL specs. In the Tier 1 days they were always thinking about ergonomics and human factors. They did not need to hire a company; they did it themselves.

Regarding concerns about the safety of the technical system structure, someone could come to him or the safety officer. There was one safety officer for every program and 99% of the time it was the person responsible for the program. He delegated the program manager to be the safety officer. If there was still a problem someone could come to him and if he could not resolve it they could it would go to the president.

If someone had a concern and wanted to submit that concern anonymously, they could put that in the suggestion box or slip a note under a door. But senior managers had an open door policy for everything, not just safety issues. There were no issues that he was aware of from the flight test side for the PF04 flight. In the past he had a crew chief come to him about concerns with transitioning the vehicle to Virgin Galactic.

Pete Siebold was the safety officer for flight operations. In the control room, the safety officer was the test conductor, Todd Ericson, if Pete Siebold was flying. During ground testing such as rocket motor burns, there was a range safety officer whose duty was to make sure all was okay. If the range safety officer was not happy he would shut the test down.

Pete Siebold reported to Ben Diachun.

Scaled Composites's safety policy was written in the engineering handbook in desktop procedures. On another program, Northrop Grumman, the parent company, wanted the system

---

them to perform piloting actions while being subject to varying levels of vibrations. This test was performed to set the rocket motor stability requirement for the development, and all of the ground qualification rocket motor firings had to be set below this vibration level in order to pass.

[6] In a letter from Scaled Composites dated May 7, 2015, Mr. Bird added the following clarification to his interview summary: Scaled retains most of the cockpit layout/human factors development internal to Scaled. Scaled Composites is a research and development company and has the flexibility and, in fact, encourages its designers to develop iteratively and be willing to change things up in the design area in an effort to see if the design can be improved over a previous version. Scaled believes it will never have the opportunity to improve the product only by following MIL specs. Scaled did not hire an outside company to design the cockpit or for the development of pilot procedures.

safety guy to come.[7] It made him angry. The person from Northrop did not relieve any duties that program managers had. Mr. Bird did not believe it was part of their culture to have someone come in and oversee them. The Northrop person did not find anything of note and made no changes to their operation. This occurred about 4 years ago.

He did not participate in the debrief following PF tests 1-3, but said he probably should have. The program started 8 years ago and he had built several aircraft during that time. SpaceShipTwo was a "well-oiled machine" when he got to it.

Regarding the hazard analysis/system analysis, it took a long time to go through every single component. Niki Dugue did that on the Tier1B program.

He saw the accident crew the morning of the accident flight about 0830. They were geared up and looked excited for the flight. He did not notice anything wrong with Mike Alsbury.

The interview ended at 1448.

[7] In a Scaled Composites letter dated May 7, 2015, Mr. Bird provided the following clarification to his interview summary: Four years ago, the parent company Northrop Grumman assigned a full-time systems safety person who was not an existing Scaled employee to a separate and unrelated program. He was upset at the idea of bringing in an external person to oversee safety because it was not consistent with Scaled's culture to have someone from outside the company oversee its programs. He was also concerned that having an external person delegated to safety concerns would negatively impact the design engineers' independent safety considerations.

Interview: Aaron Cassebeer, Project Engineer, Scaled Composites

Date: November 5, 2014
Location: Scaled Composites; Mojave, CA
Time: 1500 PST
Present: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA); Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites
Representative: Robert Craft, Counsel, Holland & Knight

During the interview, Mr. Cassebeer stated the following:

His full name was Aaron Sabey Cassebeer and he was 29 years old. He was a project engineer at Scaled Composites and had held that title for 13 months. He was hired by Scaled Composites in July 2007 as a design engineer. Before working at Scaled Composites he graduated from Lehigh University with a B.S. in Mechanical Engineering. He was not a pilot.

He had been involved in the design of the SpaceShipTwo feather system. The system was pneumatically powered and completely mechanical. There were separate feather actuation and lock systems; they were separate systems. The feather lock system had an over-centering hook that engaged a pin and held the feather closed during the boost and gamma turn. When deployed the feather moved from the closed position at zero degrees to the open position at 60 degrees. To operate the system Scaled Composites designed custom actuators. Pneumatic lines ran to the crew station/center console to four-way ball valves which delivered air pressure to the correct side of the actuators.

The feather actuation valves were actuated by pushrods from the handle to the valves. The feather lock valves were actuated by pull-pull cables on pulleys from the ball valves to the handle in the center console. Additional system components included instrumentation and filters.

The only feature to prevent uncommanded unlocking of the feather was a pair of detents for the handle in the center console. The handle was g-force resistant. One reason detents were incorporated was because the handle looked like a throttle lever. The detents required that the handle be moved sideways before being moved down. This was a concern brought up by David Mackay. The detents also protected against the handle being moved by g-forces and insured the pilot intended to move the handle. The mechanism was stiff such that, past the detents, significant g-force would be required to move the handle. During the design he did not recall other safeguards being discussed. He was involved with design and procedure development. The original intent was to open the locks, not as currently shown on the test card, but effectively when in space. Several engineers had ongoing conversations regarding jammed actuators which lead to the procedure of opening the locks during boost at 1.4 Mach. An inherent system risk was a jammed actuator. An obvious scenario was getting to space and not being able to unlock the feather due to a jammed actuator despite the cable interconnect. SpaceShipTwo was not designed for a feather down entry. Systems safety analysis assumed an actuator failure rate of 1 x 10 -6, but the engineers did not believe the actuators would be that reliable. A jammed actuator was not taken into consideration when designing system. To mitigate feather down reentry risks which could come from a single jammed actuator, an easy procedural change was to unlock the feather on the way to apogee, so they could abort early and stay out of a feather lock reentry.

The feather locks were cycled twice before release, one time at altitude to make sure they worked after cold soaking; they could also check the system itself, like pressure. They were pretty sure if the system worked at altitude that it would work at apogee or at 1.4 Mach. Many cycles of the system had been done without failures. It was easy and low risk to cycle the locks. Cycling allowed them to build up confidence in the system early on. The feather locks sole purpose, and where it was critical, was for the gamma turn about 5-8 seconds into the burn, otherwise the system was not safety critical. There were no other situations when the pilots would use the feather system. The feather system was designed to be used when weightless when the rocket motor was turned off; it was a reentry device. The feather was used for recovery during glide flight 16 when the aircraft went upside down, but that was a special case that engineers did not anticipate. He did not know the limits for airspeed, g-loading, or altitude for operating the feather system. He deferred to the aero group and stated that he designed to the requirements provided to him by the aerodynamicist. He did not recall when the procedures to open locks during boost were developed, but they had been running that procedure since PF01; the procedure could only be run during powered flight.

The system architecture was based on SpaceShipOne. The original SpaceShipTwo architecture was developed before he was hired in 2007. The cockpit interface had already been done by Matt Stinemetze. Some parts were already drawn in the computer aided design (CAD). Mr. Cassebeer made the shop drawings, and implemented and installed the system. The feather vent system had been in place since 2006. The design engineers brought concerns to management and it was decided to keep the system as it was. The actuators had always been a single point failure regarding jams and jammed actuators "taking down the vehicle". Other concerns were disconnecting an actuator, installing valves, operating pressures, and a clogged pneumatic design.

Before passing the detent, the feather lock levers moved about ¼ inch at the stop and about ½ inch at the handle. There was a detent to keep the lock handle in the open position, although it was probably not needed. Per the original design intent the feather lock handle blocked the feather extension handle. The feather locks were designed to be strong enough to not break if the feather was commanded open with the locks closed. The pilot force required to push the feather lock handle down to command the open position was about 10-15 lbs. After pilot complaints, efforts were made to reduce the required force to move the lock handle to the open position. The forces required to move the feather unlock lever was not representative in the simulator as they were much lighter than in SpaceShipTwo.

The feather (not the lock) valves were actuated by an 18-24 inch "lawnmower start stroke" from the center console. The feather handle actuation force was less than the feather lock, but ergonomically based. Asked if they referenced any ergonomic texts for how hard a pilot would have to pull, he did not believe he ever personally referenced a Mil spec. He knew there was a Mil spec that dealt with that, but he did not know the title and he did not think he looked at it to verify the design; but Mil specs represented a different situation than they had. He was not sure if Matt Stinemetze looked at any. At one point there was a change in the ball valve which lead to different handle force characteristics. Pilot input was sought to verify acceptable forces. The complaints raised were on the forces needed to unlock the system, not the feather actuation handle. The valve change was done before the first glide flight of the vehicle, prior to October, 2010. After the vehicle was built, Mr. Cassebeer personally raised and lowered the feather with the vehicle on the ground about 10 times in a pressurized test. He also operated the feather locks about 100 times.

Regarding any failures of a pneumatic actuator, he said the speed brake actuator was similar to the feather lock actuator. On one occasion the speed brake actuator suffered a leak due to cold soak, but it did not jam. There was no structural failure. This failure mode seen on the speed brake actuator would not happen on the feather unlock actuator since one side of the actuator was always vented to ensure there was always positive pressure across the piston.

It would not be practical to design an electrical override since the original design required no electrical power for the system to function. It was uncertain on how a mechanism would receive information about the aircrafts speed. Pilots have been differentiating that.

None of the engineers had a human factors background. During the design phase, system safety was always conferred with. They were always thinking of failure modes and which one was more likely to happen. Other human factors concerns were addressed by a committee of the project engineer, aerodynamicist, pilots, and design engineers. The 5-6 people involved on the committee really played a role in guiding where they were today. Mr. Cassebeer stated that the design decisions of the vehicle were agonized over for years and that they were not quick decisions.

The interview ended at 1545.

Interview: Robert Withrow, Project Engineer, Scaled Composites

Date: November 5, 2014
Location: Scaled Composites; Mojave, CA
Time: 1555 PST
Present: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA); Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites
Representative: Bob Carter, Counsel, Holland & Knight

During the interview, Mr. Withrow stated the following:

His full name was Robert Warren Withrow and he was 60 years old. He was a project engineer at Scaled Composites and had been in that position for 2-3 years. When hired by Scaled Composites about 5 years ago, he was a design engineer.

He was responsible for AST permitting. He spent a lot of time explaining the methodology of the system safety analysis to AST. He took a training course in system safety analysis about 3-4 years ago that was offered at Scaled Composites arranged for people involved in the Tier1B project, including FAA personnel.

Most of his time was spent in areas other than the feather system, such as the propulsion system and things related to the propulsion system, and questions related to reentry.

He was recently given responsibility for being the flight test project engineer. His responsibilities included making sure simulator sessions were accomplished. He organized the simulator sessions, made sure the appropriate persons attended the sessions, and made sure any issues were appropriately dealt with.

Issues from the simulator sessions were tracked in JIRA and given a priority. Issues were things such as bugs in the simulator, or an emergency procedure that needed to be revisited. He tracked maybe 40-50 items during the evolution from when he became the flight test engineer until PF04. All items were triaged but he did not recall what the specific items were. He did not recall any issues related to the feather system.

He was in the control room for the PF04 simulator sessions. No issues stood out to him. It seemed that the team was training well and the team improved with each simulator session. They tested a lot of off nominal events and each simulator session seemed to be conducted in the same way. The instructors had a plan of what they intended to do, there was a prebriefing, a debrief after each of the 2-3 runs, and then an overall debrief with actions to be discussed. They then proceeded to the next simulator session.

He background was in electrical engineering and he worked in the IT industry specializing in high reliability software prior to coming to Scaled Composites. He also previously ran his own company. He was a commercial pilot and was building an airplane. Many years ago in college he had a course in human factors.

There were two hazard analysis volumes. There was a functional hazard assessment for WhiteKnightTwo and a functional hazard assessment for SpaceShipTwo. For hazardous or catastrophic items, there was a separate fault tree. Most of the fault tree construction was done by Niki Dugue. There was a fault tree done for the feather system. He had looked at the feather system fault tree analysis in the last couple of days. Function 13 was a procedural mitigation for doing the feather lock checks before takeoff and during climbout and also unlocking at 1.4 Mach.

There was no inadvertent pilot actuation of unlock considered in the fault tree. He would not expect there to be one because the methodology did not include those kinds of things. Asked to clarify those “things”, he said there were a number of assumptions documented in volume 1 of the hazard assessment. One was that the crew did the appropriate action at the appropriate time. If a pilot had to take an action to mitigate something, it was assumed the pilot did it correctly. There were sometimes additional mitigation measures like the CAS message coming on at 1.5 Mach to remind the pilots to unlock the feather. The associated procedure was mentioned in the fault tree, but was not specifically covered.

The interview ended at 1610.

Interview: Matt Stinemetze, Tier 1B Program Manager, Scaled Composites

Date: November 6, 2014
Location: Scaled Composites; Mojave, CA
Time: 0935 PST
Present: Katherine Wilson – National Transportation Safety Board (NTSB); Christy Helgeson – Federal Aviation Administration (FAA) Michael Masucci – Virgin Galactic; Clint Nichols – Scaled Composites; Operations Group: Brett Vance – Federal Aviation Administration (FAA)
Representative: Gary Halbert, Counsel, Holland & Knight

During the interview, Mr. Stinemetze stated the following:

His full name was Matthew Wayne Stinemetze. He was the Tier 1B program manager and had been in that position for about 6 years. He had worked for Scaled Composites for about 16 years and had held positions of design engineer and then project engineer for multiple programs at Scaled including the SpaceShipOne and SpaceShipTwo. About 1 year into the SpaceShipTwo program, he was promoted to program manager. There were many lessons learned from the SpaceShipOne program; SpaceShipTwo was organized similarly but was different. In the program manager role he oversaw the program engineers for SpaceShipTwo, WhiteKnightTwo (the "mothership"), rocket motor, and avionics all of which were big efforts. The project manager roll was created to manage resources between groups. Flight test was combined in all of those groups. He was also the defacto lead engineer for the program.

Mr. Stinemetze had a large role in the pilot interface to the feather system. He said "the heart of the whole thing is the cabin." He then provided a little more background on how the cockpit was designed based on limitations of the cabin size, pilot access to the instrument panel, control wheel placement and the design eye height considerations. Due to a pilot egress concern, the center console between the two pilots was kept to a minimum size. They used a hand-selected group ("grey beards") that came out of the SpaceShipOne program, but soon realized they needed more people. They spent 6 months trying to work out the cabin and cockpit design. A design challenge they faced was the pilots having to sit high and look over the tank at the front of the spacecraft. It turned into an ergonomics pilot group study for the controls, pedals and windows; and they started to lay out the consoles. They knew stick forces were going to be high since they had set up a makeshift simulator using the SpaceShipOne multi-function display (MFD) with a control stick and seat to evaluate forces. The SpaceShipTwo control column and some of the features like Roll Boost came out of that evaluation. The feather system cockpit interface design came much later along with things like number of MFDs. About the time of his promotion was when he helped design the feather lock handle and feather actuators handle. None of the engineers were human interface designers.

In the development of the feather handles and controls it was important to understand that SpaceShipOne had some single point failures and they could not have single point failures in SpaceShipTwo. The two most important features of a spaceship were the feather and rocket motor. Feather had to work and they knew that early on in the program; it would "save you when everything goes wrong." They also believed that the locks were required for the gamma turn and the pull out after re-entry. The design of the feather was also predicated on the requirement to not feather at the wrong time and to ensure the lock was moved first. There was also a lot of redundancy in SpaceShipTwo since single point failure was not an option. A simple fault tree could not be performed since many of the parts were custom and they could not test it many times (there was no reliability data), so they relied on redundancy. Their “culture grew out of the garage.” All engineers could inspect all parts.[8] They wanted a pneumatic-based system so they could see the failures and did not have to rely on electronics. One reason was inspection and maintenance. An electrical system could mask faults and make them more difficult to diagnose and harder for an A&P (aircraft and powerplant mechanic) to inspect and repair. Second, there was already a concept of stored energy using pneumatic bottles in the aircraft so it became logical to use pneumatic air for the feather system.

The handles were also constrained by the size of the center console for egress purposes, ergonomics, and pull forces required. All of the engineers were pilots, so they had some “practical experience.” They looked at some Mil Spec guidance, but he did not recall what guidance they used however it was mostly for forces. A majority of the cockpit design time was spent on control column forces.

The modes they were concerned with were not pilot-centric and most of the discussion centered around getting the feather up, not keeping it down. There was a small window in which they counted on the pilot “to do the right thing” so they did not build any safeguards into the system. They wanted the feather to work when it was needed and if they designed to prevent an early unlock, as occurred on PF04, they might create other problems; like having so many redundancies with the feather system that it became “paralysis by redundancy.” The system was safe on paper but maybe in practicality it was not.

He caveated his answer with the fact that he helped design the system about 8 years ago, but said there were detents placed on the feather lock handle to prevent inadvertent movement of the lock handle. The design requirement was that the pilot would not deploy it outside of the requirement to use it at the correct speed. Procedurally a pilot did not unlock the feather below 1.4 Mach, but the POH should be referenced to make sure that was correct. He did not recall any discussions that he was involved with that discussed other safeguards, such as an electrical feather lock option. There was probably more than one fault tree analysis for the feather system that was documented and archived.

PF01-03 was a set series of flights with a specific motor. There were new objectives coming out of those tests and they started planning for PF04 over 9 months ago. From the flight crew’s perspective, crews were alternating between pilots Mark Stucky and Peter Siebold and copilots Clint Nichols and Mike Alsbury, although Clint and Mike were busy on other projects, so it was a little less clear who would be participating in PF04. He did not recall when the simulator sessions for PF04 started. They had some false starts along the way where they would start simulator sessions and then things changed. He was chosen as the flight test engineer (FTE) about three to four months before the accident. Jim Tighe was the lead flight test engineer responsible for outlining the test and then reducing the flight test data, to be the FTE for PF04. Jim Tighe would also designate someone to sit in the backseat on WhiteKnightTwo for the flight.

[8] In a Scaled Composites letter dated May 7, 2015, Mr. Stinemetz provided the following clarification to his interview summary: If a particular system was kept simple, then engineers were able to inspect all parts of this system.

Each person on his team was called a “chief engineer”.[9] For the past 2 years, most of his time was concerned with the rocket motor and he did not recall spending a lot of time in the simulator during the powered flight simulator sessions.

His FTE duties on the day of the accident flight involved shooting video from the FTE seat in WhiteKnightTwo of the release and watching some key mothership data parameters such as pylon health, key pressures and temperatures. He recalled no anomalies from the mothership during the flight.

As the project manager for Tier 1B, Mr. Stinemetze “hosted” the flight readiness reviews (FRRs). Not all of them, only the ones just prior to the flight. Prior to WhiteKnightTwo transition to Virgin Galactic, the program engineer would host the FRRs. After WhiteKnightTwo transferred to Virgin Galactic, Scaled Composites thought it would be better for the program manager to host the FRR because now there were multiple aircraft under different ownership. Virgin Galactic took control of WhiteKnightTwo soon after PF03, but when SpaceShipTwo was on the hooks, Scaled Composites was responsible for the safety of the flight.

He hosted several FRRs for PF04. One was held “very early” compared to previous flights due to the addition of (b) (4) on board and the new rocket motor (RM). A “delta” FRR was held just prior to the flight to wrap up actions on the (b) (4). At the last minute, he was uncomfortable with what the (b) (4) had done structurally and said they needed to stop and do due diligence on the loads, and the PF04 flight was postponed by 8 days. During the delay, a “town hall” meeting was held to discuss “anything else” they had not thought of that could “trip” them up. The town hall did not uncover anything that they had not already thought of, but it was a good review.

When asked about the FRR documentation, Mr. Stinemetze explained that the engineers may prepare a presentation and participants included the vehicle owners, flight crew, crew chiefs, control room engineers, managers and independent subject matter expert reviewers. The FRR would generate actions and assign action items and all got address and documented along with the participation records. As the host of the FRR, he would try to make sure that people were doing their actions. All actions and action closures were saved in folders as well as all concerns. There were over 80 actions from the FRR and many of them were (b) (4) related.

He clarified that the FRR was run by him and the town hall was run by Cory Bird. The town hall was less formal and had more anonymity. Cory Bird would collect the action items from the town hall that were for Mr. Stinemetze and Mr. Stinemetze would roll those actions into the FRR actions. Cory Bird, Pete Siebold, as the director of flight operations, and a structures “guru” were on the FRR board and they would advise management; Mr. Bird was the FRR board chair.

[9] In a Scaled Composites email received on May 27, 2015, Mr. Stinemetz provided the following clarification to his interview summary: Mr. Stinemetz was the chief engineer for the whole program. Working under him were project engineers that were like "chief" engineers for each major portion of the program including the SpaceShipTwo vehicle, the flight test program, the avionics, the rocket motor, and the mother ship.

Mr. Stinemetze had many conversations and meetings with Pete Siebold leading up to PF04 about whether they were pushing too hard and needed to slow down. Mike Alsbury was not involved in the conversations too often since he was in and out on another project. Mike Alsbury attended all FRRs, mission briefings and card reviews and did not have any concerns that Mr. Stinemetze recalled. Mr. Stinemetze had been working towards this flight for a long time. He felt pressure from the customer, Virgin Galactic, to get the flight off, but he delayed when he felt they were not ready. He had 100% support from his management to stop the flight if they were not ready. The target date for the flight had been set for about 1 month prior to the delay. Later in the interview Mr. Stinemetze explained that the perceived pressure from the customer came from some frustration within Virgin Galactic management that the last minute load issues and analysis had not been found and completed earlier in the program. The reason he delayed the flight was because he was concerned they had not captured the load. He said they were stopping and did not get anyone's permission to do that.

Mr. Stinemetze explained the safety culture at Scaled Composites and said it would be hard for someone outside the company to understand. He emphasized that all employees were empowered to make safety calls and decisions. Whoever led the team, for example designing the motor, was the "safety guy." They would not have picked someone for a leadership role that was not a proponent of safety. Everyone was a quality assurance representative and a safety representative and everyone took that role very seriously. They worked with the end users of the process and they knew the risks.

After the rocket motor (RM) nitrous oxide accident in 2007, Northrup Grumman came in to review their safety culture. They seemed to eventually, after two days of meetings telling them what they were doing right or wrong, they left saying they were impressed with Scaled Composite's safety system. The engineering handbook included the specific safety responsibilities and a mission safety statement. They had not had any training on safety culture, but there were short courses, mentoring, and "grey beard" panels after that incident. He was opposed to signing on the bottom line and saying they approved something; people could start to second guess their decision.

His personal lessons learned from the 2007 accident included limiting the people involved to those that had a role and needed to be there during hazardous tests; a more rigorous FRR process, better handbook guidance, and more time spent doing fault tree analysis. They had tapped some outside consultants, but did it all internally now. If any employee at Scaled took safety in a cavalier manor, they were "not welcome here."

On the day of the accident, he was sitting in the FTE seat of WhiteKnightTwo with Clint Nichols in right seat and Dave Mackay in left seat. He had concerns about the rocket motor (had previously seen false starts[10] with the rocket motor), rocket motor weights and rocket motor weights; however, these concerns had been addressed prior to PF04.

He had safety responsibility as program manager.

---

[10] In a Scaled Composites letter dated May 7, 2015, Mr. Stinemetz provided the following clarification to his interview summary: programmatic and design false starts.

The primary use of the feather was for reentry, but in the flight test program they tried to open the envelope. They tested the feather in different atmospheres. When something bad happens, they threw the feather out. The feather system had been tested subsonic and had been used to recover the aircraft from a flat spin on a glide test flight in the past. The POH defined the flight envelope, Nx and Nz, emergency procedures, and non-normal procedures on when to use the feather.

As the lead engineer and with a structures role in mind Mr. Stinemetze described again some of the design points of the feather system. He was involved in the decision to unlock the feather. During the SpaceShipOne days the feather was unlocked when they needed it. They knew they had single point failures in SpaceShipOne in that if the locks failed, the feather would not unlock. But they knew the feather was needed to reenter safely, so they added redundancy which also then introduced more failure modes. In SpaceShipTwo, they minimized the risk of a jammed feather lock by unlocking the feathers prior to rocket motor burnout based on hinge moments. Dealing with the redundancies was complex.

Based on the flight card, max apogee for PF04 was expected to be approximately 135,000-138,000 feet. One of the primary objectives for the flight was a supersonic reentry at 1.2 Mach. It would be the first supersonic reentry flight. And they were testing the rocket motor with the (b) (4) modification. They believed it would be a (b) (4) and then it would be up to Virgin Galactic to decide what motor to use in the long term.

He had never heard of a pilot actuating the feathers at the wrong time.

When they had looked at the feather control design, they had looked at cables versus push rods and conducted a trade study for final design. The design team was adamant against any software or electronic controls. Pneumatics was the best answer. He did not really recall any explosive options being discussed while he was on the feather design team. They had never really discussed how to make the feathers unlock differently. They did look at the actual actuator several times but not at the locks. When asked what concerned him about the feather system, he stated that the locks were not in the top 10 of his concerns. He did have concerns that the criticality of the feather system would not have been passed on to the future Virgin Galactic/The Spaceship Company (TSC) engineers. He was not worried that the pilots "wouldn't get it"[11] and he made sure the actuators were robust. Some actuator testing had been accomplished already by Virgin Galactic/TSC engineering and more environmental and structural testing would be done by Virgin Galactic after the transition of SpaceShipTwo.

The last minute loads analysis was validated by a combined Scaled Composites/TSC team (including the project engineer) looking at some special case loads. Mr. Stinemetze stated that they were "ready to roll" on the day of the flight and there was no direction to go fly if they had not been ready. He had no reservations about flying on the day of the accident.

He concluded that he believed in the safety culture at Scaled Composites.

[11] In a Scaled Composites letter dated May 7, 2015, Mr. Stinemetz provided the following clarification to his interview summary: Scaled spent time working with the Virgin Galactic team to make sure that the engineers thoroughly understood the system.

The interview ended at 1055.

Interview: Michelle Lynn Saling, Wife of Michael Alsbury

Date: January 28, 2015
Location: Mojave Airport meeting room
Time: 1240 PST
Present: Katherine Wilson, David Lawrence, Lorenda Ward - National Transportation Safety Board (NTSB)
Representative: Michael Dworkin, Michael L. Dworkin and Associates

During the interview, Ms. Saling stated the following:

Her name was Michelle Lynn Saling. She and her husband first met in college. He was not a pilot when they first met. His background included a BS in Aerospace Engineering, and he began work for a sister company to Scaled Composites. He had an interest in flying, and got his licenses in Delta, Colorado. In 2000, they moved to Mojave.

He did some flying outside of Scaled Composites, and had flown the family on various trips from several different airports. He did not own his own airplane, and rented the Scaled airplanes for trips and to stay proficient. He flew often, but she was not sure how many hours he had.

He was personally an amazing man, intelligent, kind and humble. He loved life, loved to fly airplanes, and loved his family and the outdoors.

He generally went to bed early around 2100 to 2200, but it also depended on what he was working on. Prior to sleep, he would read, but how long he read for depended on how tired he was. She characterized him as a sound sleeper. In general, he would wake up around 0430-0530 during the weekdays, and around 0630 on the weekends. He did not have any daytime sleepiness, and he was generally rested. He did not typically take naps during the day.

He did not have a normal work schedule, and would sometimes work on the weekends depending on what project he was working on. That was the same for the week of the accident.

He did take vacation days, and they recently had a family trip to San Francisco for 2 nights. She thought that trip may have been over a weekend. They lived in Tehachapi, California, and the drive to work typically took about 30 minutes. He mostly drove to work by himself, but would sometimes commute to work with Sean Lynch.

His activities the weekend prior to the accident included his daughter’s birthday party and a roller skating party. There was nothing unusual about his activities that week, and the weekend was normal. They had a “great weekend.” She could not recall what time he woke up on Monday, October 27, and was not sure if that was the day he traveled for work, or if it was on Tuesday. It usually took him about 30 minutes to get ready, and he would leave about 0500. She said his work day typically started about 0700 but he would get there before that. She did not recall what time he went to bed on Monday. She could not recall if he traveled to an off-site location from Tuesday October 28 through October 29, and could not recall what time he woke up on Tuesday morning.

He normally ate breakfast, which included yogurt and fruit or a bagel, and a cup of coffee. She did not recall if she talked to him on Tuesday, October 28, and did not know what his schedule was like while he was gone. He usually could not talk when he traveled.

On Wednesday, he got home about 1715, and he watched a football game with his family. He went to sleep that night around 2200 after reading.

He woke up on Thursday, October 30, at about 0500, and she said he slept fine. She could not recall his activities on Thursday, and did not recall what he ate or if he drank any coffee. He got home from work on Thursday around 1600. His activities on Thursday included family activities outside of their home. They got home around 1800 Thursday night. They discussed the next day's flight, and he had no concerns about the flight. She did not recall him receiving any phone calls that night, and he got to bed around 2100, falling to sleep right away.

He woke up on Friday, October 31, at about 0300 and she said he slept well. He showered and ate, probably an apple and granola bar. She was not sure if he had any coffee. He gave her a hug and a kiss and left for work at about 0330.

On the morning of the accident, after he left for work, they only communicated through text messages about their children attending the launch. There was nothing unusual about his activities or communications, and he appeared happy.

She characterized his health as generally healthy, with an occasional cold. He had not had any recent injuries or illnesses the week of the accident. He exercised regularly, and liked to mountain bike and hike with the family. He would also use the gym when he traveled.

He did wear glasses, and did not wear any contact lenses. She was not aware of any problems with his color vision. He did not have any problems with his hearing, and Scaled regularly tested his hearing at work. He had not been diagnosed with a sleep disorder or discussed any sleep concerns with his doctor. He did not take any prescription medication, and only took an occasional vitamin. The last time he had an alcoholic beverage was the night before the accident. He had a small glass of wine around 1900-1930. He did not use any tobacco products, and occasionally would have a soda containing caffeine. He did not use any illicit drugs. In the 72 hours before the accident, he did not take any drugs, prescription or nonprescription medication that could have affected his performance.

In the 12 months preceding the accident, he had not had any major changes in his health or financial situation (good or bad) that might have affected his performance. There had not been any major changes in his personal life (good or bad), and she said they were a "happy family."

Her husband enjoyed working for Scaled Composites, and he had no concerns about his work. He did not talk about work with her. He enjoyed flying, and she did not know if he had any concerns about traveling to an off-site location the week of the accident.

He had received commendations for his performance at work, and had just received an excellence award, though he was not present to accept it. He also received a president's award.

He had never been disciplined for his performance at work. He had not been involved in any previous incidents or accidents.

The cell phone he used was issued to him by Scaled Composites, and was the only cell phone he had. He did not have a separate personal cell phone.

The interview concluded at 1315.

Following the interview, Ms. Saling provided an additional statement[12]:

Mike was an amazing man in so many ways. He was kind, generous, humble, intelligent and methodical. He was a loving and attentive father and husband. He loved spending time with family. He always made time for us and no matter what we were doing we had fun together. He constantly had a smile on his face and was positive and cheerful. He enjoyed being outdoors-hiking, fly fishing, camping, mountain bike riding. He was a reliable, dedicated employee and worked his hardest. He loved flying. He was always there to lend a helping hand and was a great teacher and friend to many. He had a way with being aware of people's feelings and was very respectful. Mike loved life. He is so very special and was my best friend.

[12] Statement received via email on Friday, February 6, 2015, from Ms. Saling's representative, Mr. Michael Dworkin.

Questionnaire: Peter Siebold, Test Pilot, Scaled Composites

The following questionnaire was completed by the pilot and returned to the NTSB on November 25, 2014.

Name: Peter Siebold

Age: 43

Monday, October 27, 2014

Question	Answer
What time did you go to sleep?	9-10 pm
Did you have any trouble falling asleep? If yes, why?	no
Were there any interruptions to your sleep? If yes, what were they (e.g., bathroom use, dog barking)?	no

Tuesday, October 28, 2014

Question	Answer
What time did you wake up?	5:30am
How would you rate your sleep quality?	Good, slept soundly with no disruptions or awake periods
What were your activities (including times) during the day? (for example, “left for work at 0700 and returned home at 1800; did family activities with family until 2000”)	Left for work at 7:00am Returned home at 5:00pm Family activities from 5pm-9pm
Did you nap at all during the day? If yes, when did you fall asleep and when did you wake up?	no
What time did you go to sleep?	9-10pm
Did you have any trouble falling asleep? If yes, why?	no

Wednesday, October 29, 2014

Question	Answer
What time did you wake up?	6:00am
How would you rate your sleep quality?	Good, slept soundly with no disruptions or awake periods
What were your activities (including times) during the day? (for example, “left for work at 0700 and returned home at 1800; did family activities with family until 2000”)	Left for work at 8:00am Returned home at 6pm Family activities from 6-8pm
Did you nap at all during the day? If yes, when did you fall asleep and when did you wake up?	no
What time did you go to sleep?	8-9pm
Did you have any trouble falling asleep? If yes, why?	no
Were there any interruptions to your sleep? If yes, what were they (e.g., bathroom use, dog barking)?	no

Thursday, October 30, 2014

Question	Answer
What time did you wake up?	4:00am
How would you rate your sleep quality?	Good, slept soundly with no disruptions or awake periods
What were your activities (including times) during the day? (for example, “left for work at 0700 and returned home at 1800; did family activities with family until 2000”)	Read in bed from 4-5am, got up early to adjust sleep pattern in anticipation for the flight 5-6am prepared for work Went to work at 6am Left work at 5pm Daughter pickup from school at 0530pm Shopping 5:30-6:30pm
Did you nap at all during the day? If yes, when did you fall asleep and when did you wake up?	No
What time did you go to sleep?	7:30pm
Did you have any trouble falling asleep? If yes, why?	Slightly harder than usual due to earlier time
Were there any interruptions to your sleep? If yes, what were they (e.g., bathroom use, dog barking)?	no

Friday, October 31, 2014

Question	Answer
What time did you wake up?	2:45am
How would you rate your sleep quality?	Good, slept soundly with no disruptions or awake periods, shorter than usual
Did you feel rested when you woke up?	Slightly less than usual due to early rise
What were your activities (including times) prior to the departing for the flight?	Prepared for work 2:45-3:45am (shower, breakfast) Left for work at 3:45 Arrived at FAITH to view vehicles at 4:15am Arrived at Scaled hangar 78 at 4:35am Prepared for briefing 4:35-5:00am Briefing 5:00am-6am Waited for nitrous temp to rise 6am-9am Stepped to SS2 approx 9am
What did you eat or drink prior to departing for the flight?	Breakfast at 3:30, 1 cup coffee, 1 serving of scrambled eggs 1 cup coffee at approx 7am

How long is the commute from your home to Scaled Composites? 35 minutes / 30 miles

In the 72 hours before the accident, did you take any medications, prescription or non-prescription (including vitamins)? If yes, what medications and what was the amount?

Yes The following were reported to my AME at my last FAA physical

(b) (6), daily AM

(b) (6), daily AM

In the 72 hours before the accident, did you drink any alcoholic beverages? If yes, when, what and how much?

Yes 10/30/14 1 beer 6pm

10/29/14 1 beer 6pm

10/28/14 unknown but possible

Have you ever seen a doctor for problems sleeping or been diagnosed with a sleep disorder? If yes, when and what was the diagnosis?

No