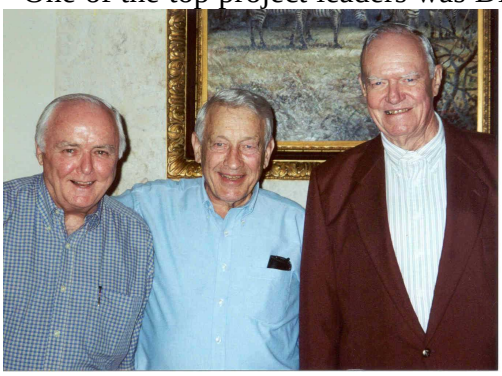
More Never Told Tales of Pratt &Whitney

By Dr. Bob Abernethy

Presented to the Roadrunners and the J58 Reunion
March 26, 2004

I'm here to tell some stories from the fifties and sixties, **the golden age of aerospace**. It was the best of times. And we worked with the best of people, the engineers, the technicians, the project leaders and of course, the pilots whom we rarely ever met except at flight test. So I am thrilled to be here tonight with the Roadrunners!! After all these years here we are face-to-face. I want to thank Don Norquist for coordinating this reunion and twisting my arm to be here! And I want to thank you all for coming. Many of our friends have left us; Bill Brown, Moe Kuchera, Kelly Johnson, Ben Rich….I wish they could be here tonight.

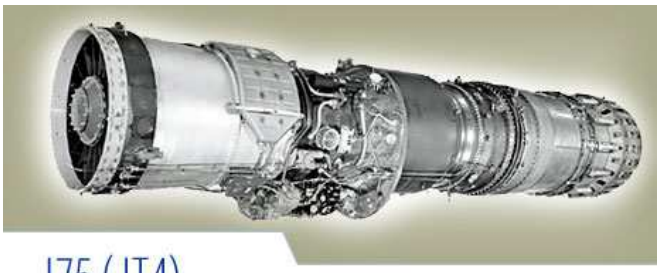
One of the top project leaders was Dick Mulready who wrote a book about this subject; "Advanced Engine Development at Pratt & Whitney." The preface to the book starts with these words: **"This book celebrates the wonderful projects on which we worked at P&W during the almost magical quarter century after WWII. It was a time when going to work was fun, with a new challenge arising almost daily. The feeling of loyalty, both upward and downward within our company, was palpable. The work was pioneering, never having been done in the past, and it was very exciting. Dick Coar** (in the middle) was the Chief Engineer of both P&W Florida and Connecticut and later became Senior Vice President of UTC. He had two project managers working for him in Florida, **Bill Brown and Dick Mulready (on the right)**. They both headed up top secret projects.



In 1955 Jackie Gleason starred in the Honeymooners and Brian Shul was seven years old! I was discharged from the Navy to join the P&W J75 Engine Performance Group. This was the most advanced engine at the time. It powered the F105, F106, F107, Boeing 707, Douglas DC8, the U2, and many other aircraft. For performance analysis there were no computers or even calculators, so we did it all with slide rules. Every engineer had a small one in his shirt pocket and a large one in a holster on his belt. On a good day with overtime, with the help of a good aide,. I could calculate the performance at one point for this twin spool jet engine. My boss was Norm Cotter, and I worked for him for the next quarter of a century.

One morning that year, Wright Parkins, the president of P&W had three admirals in his office that had arrived to witness the first test of a **new design of the J75 engine**. The admirals asked for a plot of fuel consumption against thrust. Parkins sent a project engineer to Norm to get the plot, ASAP. Norm called me over and I told him the engine hadn't run yet, we had no data, no plot. The engineer said we had to have the plot for the admirals. Norm told me to go fudge one, which I did. He looked at the curve and said it's too high, lower it about this much. So I refudged the plot, labeled it and Norm said okay. The engineer said no, no, it has to have data. So Norm took out his symbol maker and told me to fake data points on the plot. The engineer grabbed it and started to run off. Norm said to him, "Don't forget to make us a copy, we have to have a copy!"

A few moments later I got a call from **Mo Kuchera, the lead test engineer,** that he was ready to test the new engine and I went to the test stand. In East Hartford these are large U shaped concrete stands about 60 feet high, inlet air comes in one side, exhaust on the other side and engine in the bottom. The blockhouse is above on the side with two small windows looking down on the engine. Mo had the engine at idle when I arrived and he told me Design Engineering said there was a little HCF



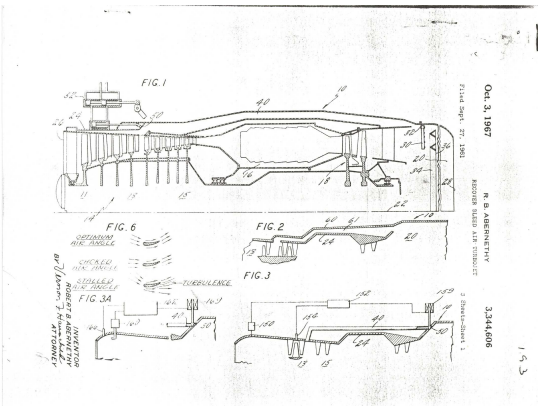
problem around 7000 RPM so he was not going to linger in that range. Parkins and the admirals arrived and we crowded around the windows. Mo said to the test foreman take her up to 9000 rpm, quickly. The engine blew up catastrophically!!! Fire filled the test stand. Turbine discs were spinning around the walls. Parkins and the admirals left immediately. The next morning Parkins received a telegram from the Navy. They liked the fuel consumption plot and asked for six more copies!! They had the original and we had no copies. So…Norm and I had to reconstruct the fudged plot…. Lots of fun.

In late 1957 PW had two top secret, black, engine projects that were to use poison fuels! Not a good idea in the middle of Connecticut…how about the middle of the Everglades?? **So I was invited to move to Florida**. I was assigned to the J58, a Mach 3 Navy engine. To scrub the poison out of the J58 exhaust we built a huge swimming pool with a tall tower to centrifuge the poison out of the exhaust… If it didn't work, we might wipe out the Palm Beaches so we were a little nervous. The Navy canceled the poison fuel just before we ran the first test….thank heavens!

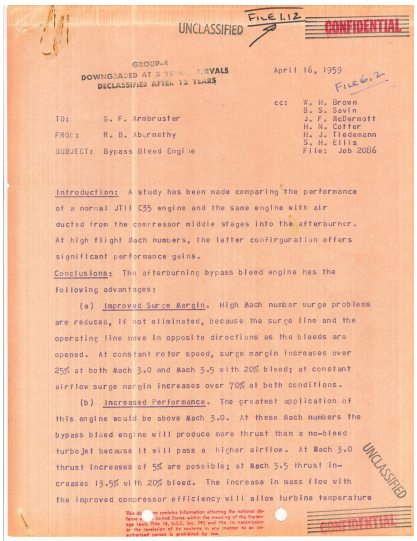
Meanwhile we heard these incredible sounds from the other test area…sounded like a cat being tortured. I could not imagine what they were doing over there in the swamps. It was the other black project, Codename "Suntan" and their 304 engine was accelerating! My good friend, Frank Williams was on the Suntan project, but we were not allowed to socialize. More about Suntan later…

My first job was to create a thermodynamic computer program to calculate the performance of the J58. My computer analyst and I worked day and night on this in the winter of '57-58. This was the second engine computer "deck" every created and I learned a lot from it. I quickly understood that the J58 would never get to Mach 3 as designed. At about Mach 2.5 the exhaust pressure was equal to the inlet pressure, the compressor was deep in surge, and there was no cool airflow for the afterburner liner that would therefore melt. This is not good. About this time Norm assigned me to head up the compressor development. I knew nothing about compressor theory so I

returned to East Hartford for education from their computer expert, Jim Fligg. I had to analyze data from the compressor rigs that Les Churchill was testing in the Willgoos Laboratory.



With a little knowledge of compressor aerodynamics I could see at Mach 3 the front stages would be deep in stall from too low airflow and the rear stages were choked preventing the airflow to increase. The same problem exists when starting the engine and P&W solution was to open "start" bleeds. This brought the front stages out of stall and bypassed the rear stages. In October 1958 the solution for all these J58 problems was clear to me. Bypass the bleed air around the compressor at high Mach number into the afterburner and it would solve the surge problem, provide cool air to afterburner and increase the mass flow and thrust significantly. Actually it converted the engine into a partial ramjet with capability above Mach 3! I called it the Recover Bleed Air engine on my patent. Here you see my drawing of the duct in my patent disclosure


UNCLASSIFIED

CONFIDENTIAL

File 1.12

GROUP-4
DOWNGRADED AT 3 YEAR INTERVALS
DECLASSIFIED AFTER 12 YEARS

April 16, 1959

File 6.2

TO: G. F. Armbruster
FROM: R. B. Abernethy
SUBJECT: Bypass Bleed Engine

cc: R. H. Brown
D. S. Savin
J. F. McDermott
H. M. Cotter
H. J. Tiedemann
S. N. Ellis
File: Job 2086

Introduction: A study has been made comparing the performance of a normal J11 E35 engine and the same engine with air ducted from the compressor middle stages into the afterburner. At high flight Mach numbers, the latter configuration offers significant performance gains.

Conclusions: The afterburning bypass bleed engine has the following advantages:

(a) Improved Surge Margin. High Mach number surge problems are reduced, if not eliminated, because the surge line and the operating line move in opposite directions as the bleeds are opened. At constant rotor speed, surge margin increases over 25% at both Mach 3.0 and Mach 3.5 with 20% bleed; at constant airflow surge margin increases over 70% at both conditions.

(b) Increased Performance. The greatest application of this engine would be above Mach 3.0. At these Mach numbers the bypass bleed engine will produce more thrust than a no-bleed turbojet because it will pass a higher airflow. At Mach 3.0 thrust increases of 5% are possible; at Mach 3.5 thrust increases 13.5% with 20% bleed. The increase in mass flow with the improved compressor efficiency will allow turbine temperature

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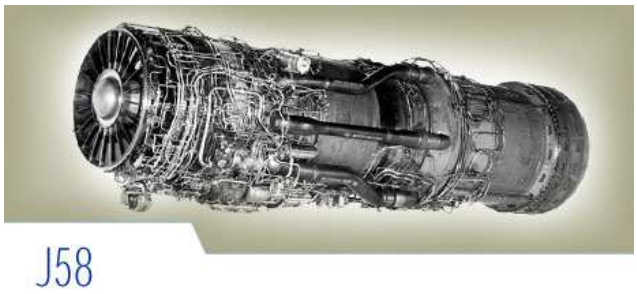
Norm Cotter did not exactly leap for my solution so I wrote him memo after memo for seven months trying to convince him. One of the problems was that if you open the bleed valves at high Mach number there would be a hiccup in the airflow which could unstart the inlet and possible destroy the aircraft. **My solution was to open the valves at a lower Mach number, around 2.0 where there would be no bleed flow and no hiccup.** Here is my report to George Armbruster, the senior project engineer on the J58 dated April 1959. George was later loaned to the CIA for the Glomar Explorer project to raise a Russian submarine from the Pacific floor.

I finally convinced Norm on a Monday in April 1959. Norm immediately convinced Bill Brown who called his buddy, Kelly Johnson, on a crypto phone and explained the concept of the **Recover Bleed Air engine,** emphasizing the Mach 3+ capability. Kelly flew to Washington and had funding for the Blackbird by weeks end. The aircraft flew with J75s about just about two years later from a top secret base, now known as Area 51 north of Las Vegas. We called it the "sandpatch." About a year later they flew with the J58-D20 engines.



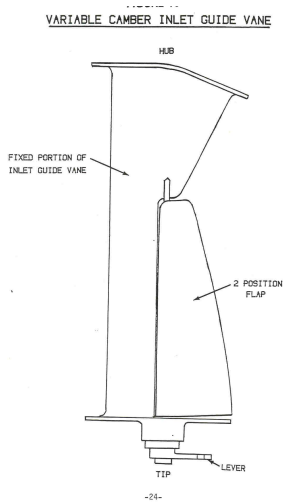
The Navy J58 Engine became The Recover Bleed Air Engine JT11-D20

About this time Bill Brown came screaming after me, "I figured it out, Recover Bleed Air, RBA, are your initials! We won't call it that anymore!" Much to my surprise I was transferred to the RL10 project, the other Florida project team. I never found out why but I suspect Kelly Johnson thought I knew too much. For example the flight condition I picked for my report was Mach 3.2, 90,000 feet.

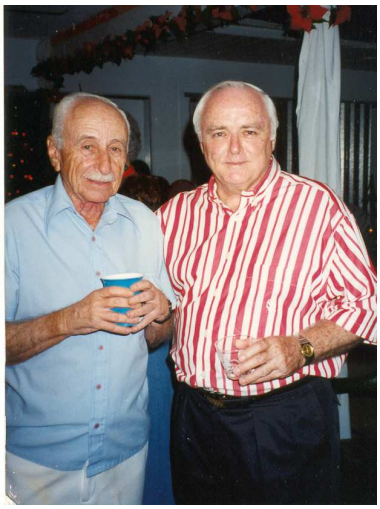
My other recommendation was to add a variable inlet guide vane to the JT11-D20 design as it would help the airflow schedule and keep the front compressor blades out of flutter. Bill Brown said, no way, that's a GE fix, but later he understood the need. Here are the performance improvements, bleeds open compared to bleeds closed. I predicted the net thrust change but not the installed thrust improvement. The increased airflow really helped Kelly's inlet performance.

Recover Bleed Air Benefits Bleeds Open to Bleeds Closed

- **Airflow Increase +22%**
- **Net Thrust Increase +19%**
- **Installed Thrust Increase +47%**
- **Installed Fuel Consumption -20%**
- **Increased Afterburning Temperature**
- **Reduced Blade Flutter**



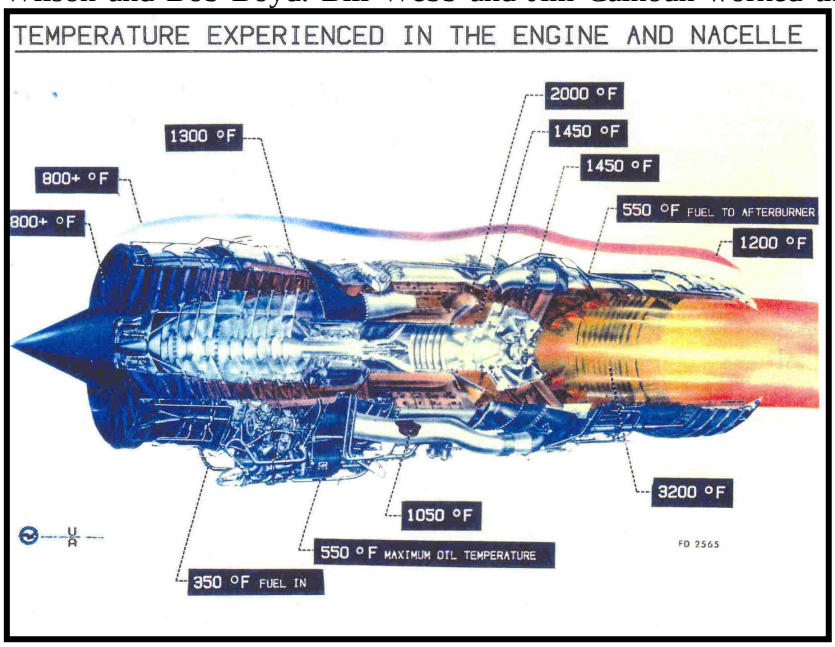
Bill Brown (on the left below) was a strong leader and a great guy. There were many stories about him. One I'll never forget related to a trip with Norm Cotter to make a presentation at the Pentagon. In those days if your charts included secret material you had to be handcuffed to this long metal tube, coming and going. We would hide the handcuffs in our suit cuff. The stewardess always wanted to check the tube in baggage, and of course, you couldn't. When Bill and Norm sat down in National Airlines First Class the stewardess said, "Mr. Brown we will have to check that tube in baggage". Brown looked at her said, "I am sorry but you can't do that." She said "why not?" He said because "it's my father's ashes." She was embarrassed and left, only to return shortly. She asked, "if that's your father's ashes Mr. Brown, why is it so big?" And Bill, deadpan, said, "He didn't all burn!" The stewardess was shocked and Norm cracked up trying not to laugh.

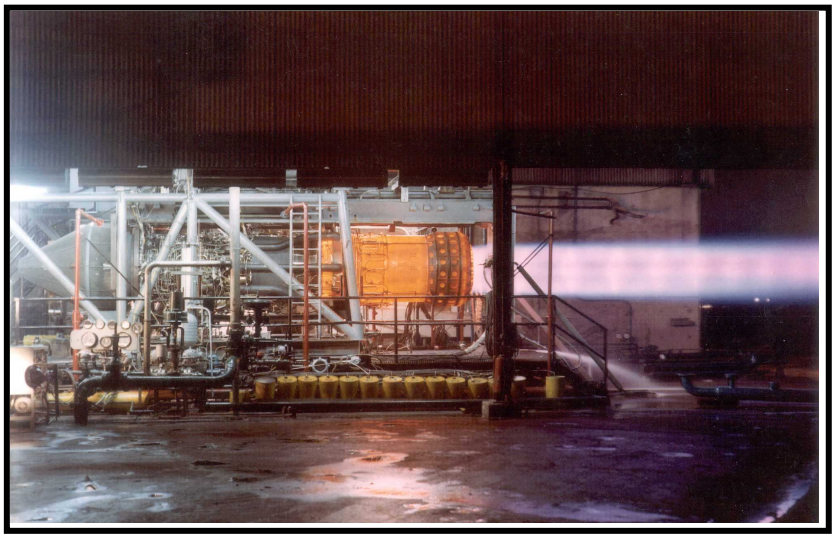


Bill "Catfish" Brown

We had many problems developing the engine, most of them due to the fierce temperatures! Perhaps the most difficult problem with the engine was finding materials that would withstand the super hot harsh environment. The turbine temperature was 400 F. over the hottest previous jet engines. Joe Moore and Roy Athey spent over a year trying to forge Astroloy disks. It seemed everything they tried would produce segregated clusters weakening the disks. The solution was to use smaller ingots and encapsulate them in a can of cheaper metal. They then used direct upset on the ingot and machined off the can. The final forging was done at Ladish with their big hammers. This breakthrough in technology led directly to the "gatorizing" process and finally to the powder metallurgy we use today, a direct descendant of the J58 technology.

The **J58 flight test** had super black security. Some of the key engineers were Moe Kuchera, Paul Wilson and Bob Boyd. Bill Webb and Jim Calhoun worked the control system. Mo tells a story about Colonel John Kelly. He said John called him one day that he could not get above Mach 1.7. What's wrong? Mo went over everything on the aircraft and could not solve the problem so he asked Colonel to try it again. Same result, he could not accelerate above Mach 1.7. Mo had the engines pulled. The second compressor disk and blades with installed backwards on one engine!





The JT11-D-20 at full afterburner on test in A-area.

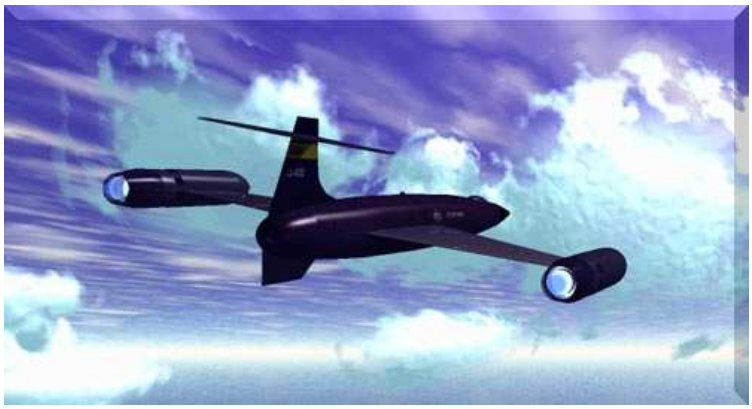
One story Bob Boyd remembers was an inlet unstart at high Mach. They were trying to expand the envelope and discovered that the inlet had a separation problem. Pilot Lou Schalk said on his first unstart that he considered punching out because the ride was so rough but he thought twice about it because things might not be better outside. Bill Brown suggested to Kelly Johnson that they install mice in the inlet. Kelly followed through on this idea and the problem was solved.

Jack McDermott told me about a visit to Area 51 to inspect an engine that had failed a second compressor blade. It was "totaled" with blades sticking through the case. While he was looking remains, Bill Parks who had piloted the aircraft, walked up to Jack and said, "I brought it in on the ther engine but if I had to go around I would have restarted this one! Jack was dumbfounded, but he did not contradict Parks.

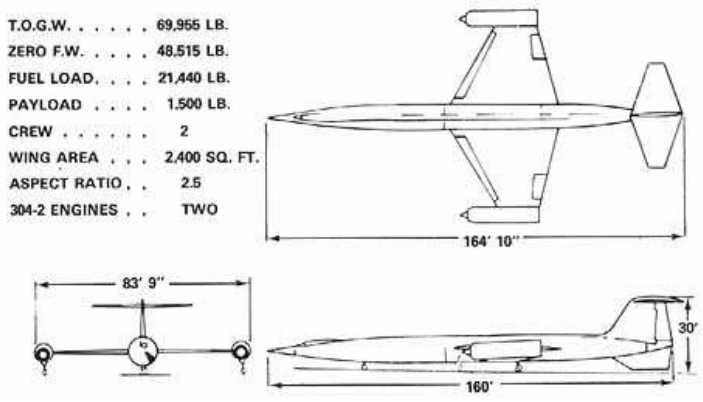
Roger Bursey remembers the special sniff test for compressor bleed air required each day when the J58 was on endurance testing in Florida. The procedure was to hold a Kotex over the bleed port. The sanitary napkin was then shipped in bottle to Joe Daley who would remove the Kotex and sniff it to make sure the air was clean. Well, Joe told Roger the Kotex embarrassed the girls in the office so he should use brown bottles to hide the contents. Roger says one of the other test engineers, maybe John Mueller, then made doodles on the napkins with a red felt pen before sending them up to Daley. Roger says Daley went into surge!! Mo Kuchera told me about another sniff test on the test stand at Area 51 but I'll skip that one as it is a little raunchy.!

There were many **control innovations**. Perhaps the most important was the electronic turbine temperature trimmer, the first electronic control ever flown. It led directly to the EEC, the F100 electronic supervisory control and finally to the full authority electronic control which in on all modern engines.

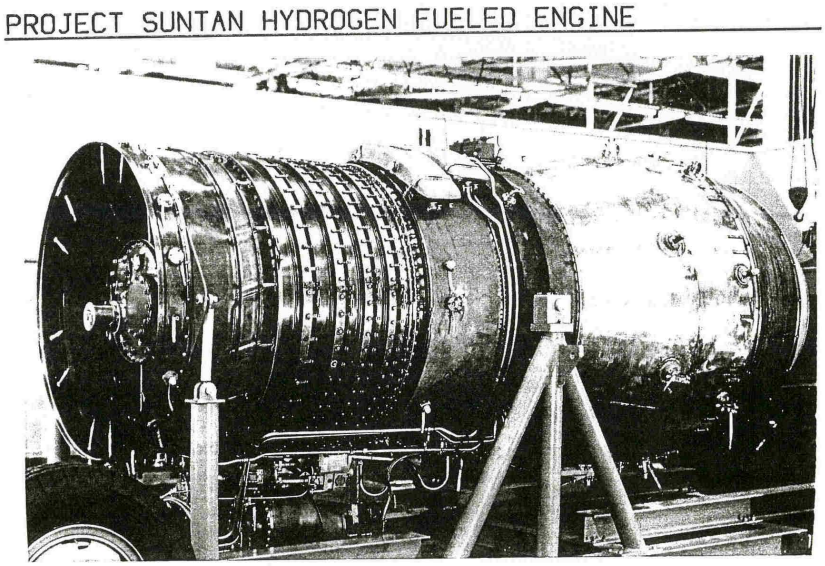
If an engine failed at test there was an award, the **pink Indian statue**, for the responsible test engineer. He had to keep the statue displayed on his desktop until the next engine failed and he could then pass the Indian. The J58s were overhauled in Florida so they were regularly at test. Around 1989 Norm Jones was the test engineer on the last J58 test. The engine failed. As that was the last J58 test Norm still has the statue. Norm do you have it with you?.



It was around 1980 before I found out from Dick Mulready that the J58 and the 304 engines were actually in competition. There were for two different Lockheed Skunkworks projects. Both were high Mach number aircraft intended to replace the U2. The 304 Suntan aircraft, the CL-400, two slides, was designed for Mach 2.5 cruising at 98,000 feet. The project was canceled by Kelly Johnson because it would have required liquid hydrogen storage facilities around the world. The density of hydrogen is so low it would have taken an aircraft the size of a football field to make the desired range.



I think Dick Coar was the only one that knew the two Florida projects were actually competing. The J58 with the bleed bypass ducts became the JT11-D20 and won the competition.



The Suntan 304 engine afterburner was only a foot long because of hydrogen's flame speed.

The cancellation of the Suntan-304 project led directly to the rocket version of the same cycle, the RL10. The RL10 was a fun project because we really didn't know what we doing, there were

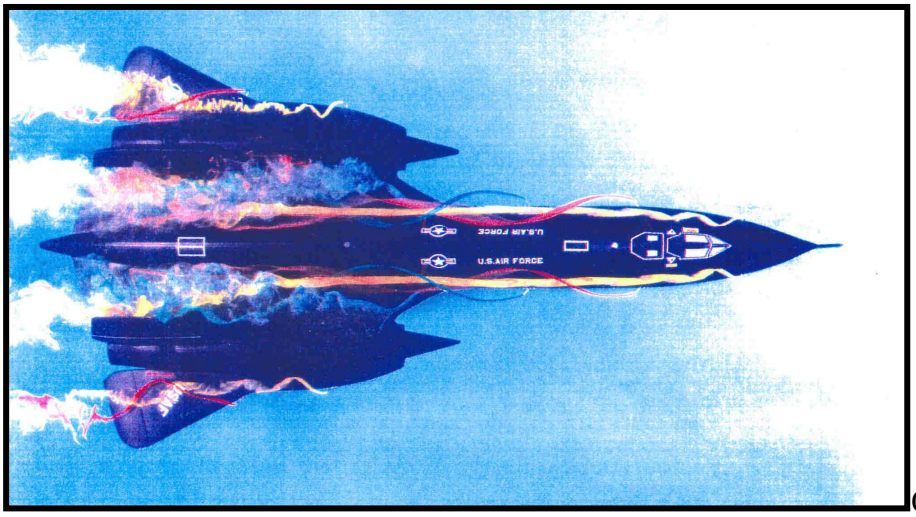
frightful stories about the dangerous hydrogen, and Mulready was a super leader. There were two real efficiency breakthroughs with this engine, first the fuel, liquid hydrogen, and second the engine pumped itself. There was no gas generator to drive the turbopumps. For these two reasons the RL10 has the highest specific impulse (like MPG) of any rocket engine in the world, even today. The RL10 is also perhaps the most successful rocket engine as it has put almost everything into orbit, out to the moon and the planets, except for the Space Shuttle and the French Ariane. It

powers the Centaur and Saturn S-IV vehicles. So the loser in the competition led directly to a real winner. Dick Mulready's wonderful book is a must read for anyone interested in the Suntan project.

When I returned from England 1965 where I had gone to study statistics, Dick Coar assigned me to manage system analysis for the new JTF17 supersonic transport engine. Lockheed was competing with Boeing for the contract and GE was our competition for the engine. There were only a few of us that knew that Lockheed was accumulating more time above Mach 3 every day than the rest of the world since the beginning of time with the double delta Blackbirds. So we were absolutely sure Lockheed would win with their double delta winged SST design. So we designed the optimal

engine for that configuration, a duct burner turbofan, the JTF17. Boeing selected a swing-wing design so GE designed an afterburning turbojet, the optimal cycle for a swing-wing SST.

Noise reduction was a difficult requirement for any SST as they always takeoff with the afterburners lit just like the Blackbirds and just as noisy. One day a two star Air Force general happened to be at Edwards Air Force Base when an SR-71 landed and took off. He said, " Weren't those engines quiet!" Lockheed and P&W went into the panic mode to find out if the J58 engines were really quiet. Our P&W noise expert from East Hartford flew out to Edwards to assist Lockheed to run a special noise test on the SR71. The data showed the SR71 was at least 6 dB lower than it should be…four times as quiet! Gordon Titcomb ordered me to find out why and fix the JTF17 so it would be quiet. I assigned my best engineer, Ted Langston, and he produced a beautiful hypothesis that explained it all. The theory was that the J58 blow-in door ejector produced Aoelian tones caused by vortexes in the exhaust that shielded the noise. An Aeolian tone is the sound produced when subsonic flow passes over a long thin object like the wind in the forest blowing through pine needles. The word comes from the Greek mythology, the God of the wind, Aeolius. Ted developed a correlation of nozzles with and without blow-in door ejectors and started a test program to prove the hypothesis. He also made a sexy water table movie showing the vortexes



in color. Gordon Titcomb called me in his office and said put together a "dog and pony show" and go convince the FAA, Boeing, and Lockheed that we know how to make the JTF17 so quiet! I said no sir, we have not turned it on and turned it off. We have not proved the concept! Gordon said we can't wait. The competition is almost over. Do you want GE to win? So I pitched it General Maxwell who ran the FAA program. He said, "Fantastic!" I went to Boeing and they loved it. At Lockheed, Dr. Stroud actually hugged me and said, "Bob. I believe it, I believe it!!!"

Within a couple weeks we heard that GE added a blow-in door ejector to their design. Then Boeing & GE won the competition and it was all over for us. About two months later the Russians put a blow-in door ejector on the TU144. Then our P&W East Hfd Noise Expert revisited Lockheed and found an error in their data reduction! As you all know, the J11 D-20 engine is <u>really</u> <u>loud.!</u> When they cycle the afterburner at night in Florida we can hear it on coast 20 miles away!

Boeing then decided the swing-wing design was too hard **and shifted their design to the double delta.** Now they had the right aircraft but the wrong engine. They wanted the JTF17. I was sent to Seattle to explain we could not restart the engine development because the FAA would not let us. The FAA would have had to admit they made a mistake giving the contract to GE. So the American

SST was canceled…because it was too noisy and would pollute the atmosphere according to the FAA. The real reason was they had the wrong engine for the right airplane. **Note that the Russian TU 144** and **Concorde** were also double deltas.

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC97-44203-3 Date: July 1997 Photo by: NASA/IBP

Russian Tu-144LL SST Flying Laboratory Takeoff at Zhukovsky Air Development Center

I have lots more stories but I will stop here. I thank you all for listening to an Irishman tell stories. In summary, I'll say it was a wonderful time in my life, it was so exciting, and the best part were the people; the engineers, the aides, the secretaries and the leaders. I am so pleased that some of them are here tonight. I don't want to eat into Brian's time but if any of you have questions I will be around for the rest of the reunion.

No time for the following stories about the J58 engine:

Frederich Rentschler, the founder of Pratt & Whitney and United Aircraft, had a "little" home on the lawn of the Boca Raton Club called "Casa Grande." There was a test engineer, Bill Cassidy, who married Frederich's daughter and lived in the big house she had inherited. Bill was a great guy to work with, lots of fun. He drove a Mercedes that we all drooled over. They were super wealthy but Bill worked anyway. He was on the J58 team. I had produced a top secret looseleaf book of J58 performance. Each page was serialized and had an orange stripe indicating its classification. One morning Bill ran out of Casa Grande to his car but remembered he had forgotten his coffee. He put the J58 Performance book on top of the Mercedes and went back in for the coffee. When he came out and drove off, he forgot about the book on the roof! There were orange stripe top secret pages blowing around Boca! Bill was out of the J58 project immediately and out of the company shortly thereafter.

The F100 engine project was the biggest project UTC has ever had and we had our best people from the J58 project working on it. Gordon Titcomb and later Jack McDermott were the Engineering Managers. Paul Wilson was the already a legend for his work on the J58 and for the fact that he liked to party a little! Paul was our lead engineer for both the F15 and F16 flight tests at Edwards Air Force Base. This was a high pressure operation with all of the Air Force and all of Pratt & Whitney up tight about demonstrating successful flights on time within the schedule without problems. There was a problem with the engine control system. Paul figured he could fix the problem on the spot if he got the right size spring. Now the correct thing to do was to notify Bill Brown, the F100 Controls Group and the Air Force. Weeks or months later he might have received a fix. Meanwhile the flight test program would be stopped dead. Paul went to Sears and Roebuck,

found a screen door spring that was about the right size, installed it on the engine and ran a ground test. The test looked good so they flew. When this story got back to Florida, Paul was the hero of Engineering, but we figured he would be fired. I'll just say he wasn't.

Here are some good references for further reading. The last two I have just found on the internet. Send me an E-mail if you want a link. weibull@worldnet.att.net

Further Reading

- **"Course Ae107 – Case Studies in Engineering – The SR71 Blackbird," Lockheed and California Institute of Technology**
- **"Advanced Engine Development at Pratt & Whitney," Dick Mulready, SAE, 2001**
- **"Gas Turbine Technology Evolution - A Designer's Perspective," Ben Koff, AIAA Paper 2722, July 2003**
- **"Liquid Hydrogen As A Propulsion Fuel,1945-1959," NASA, http://www.hq.nasa.gov/office/pao/History/SP-404/contents.htm**
- **"Military Jet Engine Acquisition," Rand Report MR-1596, 2002 http://www.rand.org/publications/MR/MR1596/MR1596.appb.pdf**