THE QUEST FOR HYPERSONIC FLIGHT
By
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I bet everyone in this room has heard the expression, "The third time is a charm!". Well, today I am going to tell you why I believe our third try at air-breathing hypersonic flight will be a charm.
But first, let me take you back to the beginning of hypersonics.

The day is Thursday, February 24, 1949; the pens on the automatic plotting boards at South Station are busy tracking the altitude and course of a rocket which just moments before had been launched at White Sands Proving Ground.
The rocket is a V-2, one of many brought to the United States from Germany after World War II.
By this time, launching V-2s had become almost routine for the crews at White Sands, but on this day neither the launch nor the rocket are "routine."
Mounted on top of this V-2 is a slender, needle-like rocket called the WAC Corporal, which serves as a second stage to the V-2.
This test firing of the combination V-2/WAC Corporal is the first meaningful attempt to demonstrate the use of a multistage rocket for achieving high velocities and high altitudes.
All previous rocket launchings of any importance, both in the United States and in Europe, had utilized the single-stage V-2 by itself.

The pen plotters track the V-2 to an altitude of 100 miles at a velocity of 3500 mph, at which point the WAC Corporal is ignited.
The slender upper stage accelerates to a maximum velocity of 5150 mph, and reaches an altitude of 244 miles, exceeding by a healthy 130 miles the previous record set by a V-2 alone.
After reaching this peak, the WAC Corporal noses over, and careens back into the atmosphere at over 5000 mph.
In so doing, it becomes the first object of human origin to achieve hypersonic flight - the first time that any vehicle has flown faster than five times the speed of sound.

The first human being to experience hypersonic flight was Yuri Gagarin of the Soviet Union when in April 1961, he re-entered the Earth's atmosphere in Vostok I at more than 25 times the speed of sound.
Later that same year, Alan Shepard became the first American and only the second human being to fly at hypersonic speeds when he re-entered the atmosphere above Mach 5 on a suborbital flight across the Atlantic Ocean.
Finally, also in 1961, Major Robert White flew the X-15 airplane at Mach 5.3, accomplishing the first "mile per second" flight in an airplane.
1961 was a very good year for hypersonics indeed.

The V-2/WAC Corporal, the early manned sub-orbital flights, and the X-15 airplane flight experiments, all showed that hypersonic flight was possible...that man could fly higher and faster than he ever had before.
Other significant events along the way include the development of Mach 25 Intercontinental ballistic missiles (ICBMs) in the 1950s, the Apollo space craft, and of course in our recent day, the Space Shuttle...all hypersonic vehicles, but all rocket-powered.

Unfortunately, the potential for rocket propulsion to generate and sustain high speeds within the atmosphere is limited by the laws of both physics and chemistry.
The efficiency of a rocket motor is largely a function of the thrust it can generate per pound of propellant, that is, fuel plus oxidizer.
Rocket design engineers have nearly exhausted all opportunities to extract the maximum possible energy from a pound of propellant.
Further improvements in propellant chemistry appear to require the use of toxic and/or highly unstable ingredients.
As a consequence, the launch weight of a modern rocket is mostly propellant.

Once the weight of the propulsion system and vehicle structure is considered, only a tiny percentage of the vehicle's weight can be allocated for payload.
Consequently, even a modest size payload requires a large, expensive launch vehicle and large payloads require vehicles of enormous size.
Could there be another way?

The Air Force thought so for the first time in the 1960s and again in the 1980s.
The second try in the mid 1980s was known as the National Aerospace Plane or NASP, and actually originated from a small DARPA seedling effort.
The idea was to combine air-breathing and rocket propulsion to allow a vehicle to take-off horizontally from a runway, accelerate into orbit around the earth, and then re-enter the atmosphere at Mach 25, finally landing on a conventional runway.
The air-breathing portion of the propulsion was provided largely by a supersonic combustion ramjet or scramjet - a fairly simple concept that, at that time, had never produced measurable positive thrust.

A major attraction of scramjet propulsion, both then and now, is that since it extracts oxygen from the air for propulsion, it theoretically at least, is much more efficient than rocket propulsion.
This characteristic translates to greater range for a hypersonic aircraft or a greater payload fraction as part of an orbital launch vehicle.
In addition, scramjets are conceptually simple in design with relatively few moving parts.
In particular, they avoid using rotating machinery like turbojet engines.
This apparent design simplicity is deceptive, however.
Efficiently combusting a fuel in a supersonic flow stream is a daunting challenge, especially when coupled with the complex flow phenomena present in the typical scramjet engine.
Thermal management to protect the internal walls of the engine poses additional demands, as does the need to design the flow path to ensure that engine thrust exceeds drag.

Air-breathing hypersonic flight poses many other technical challenges in addition to propulsion.
Since the vehicle flies within the atmosphere in order to provide air for its propulsion system, its design must address several issues that rockets largely avoid.
First, the extended duration of flight within the atmosphere imposes a severe thermal load over the vehicle's surface especially on leading edges and control surfaces.
In addition, vehicle drag is a strong function of configuration at hypersonic velocities and only a highly optimized vehicle shape, with a highly integrated propulsion system, can hope to possess any significant capability.
But efficient hypersonic shapes are typically not amenable to stable, controlled flight in the subsonic flight regimes that will be encountered at take-off and landing.
Finally, it is extremely difficult to replicate real hypersonic flow conditions over a meaningful length of test time in a ground facility due to incredible power requirements and severe thermal temperatures in the facility.
This complicates hypersonic concept development and requires that flight demonstrations become a critical part of any development program.

The NASP program was successful in that many of the technical challenges that I have just discussed were better understood by the time the program was canceled in the early 1990s.
However the program failed to achieve its stated goal: the design, development, and demonstration of a full-scale aerospace plane that could take-off horizontally, go into orbit, and return to land on a conventional runway.

What have we learned from the NASP experience and where are we going in the future?
We have learned that the ultimate goal of a Single Stage to Orbit, air-breathing, access to space vehicle needs to be achieved with a series of "stepping stone" flight demonstration vehicles over time, beginning with expendable vehicles, leading

to reusable cruise vehicles, and finally ending with reusable, accelerator access to space vehicles.
We have also learned that a series of well-focused, creative, flight demonstrations of key technologies within each one of these system categories needs to happen in order to focus the technology development and produce measurable results.

As we all know, there is nothing like a test in school to focus a student on learning material; there is no substitute for a flight test to focus our developers on making sure they understand the technology and how to use it.
Finally, we have learned that a successful flight demonstration program, with demonstrators every other year or so, is the best way to maintain support for a high visibility program.

In the Tactical Technology Office at DARPA, we are attempting to follow these lessons learned and we could use your help.
In the area of expendable hypersonic vehicles, our signature program is the DARPA/Navy HyFly program.
This program is demonstrating a scramjet engine in a Mach 6 missile for long range strike applications.

A key demonstration in the program is the viability of high temperature materials in the scramjet flowpath.
These materials must withstand internal wall temperatures as high as 4000 degrees Farhenheit over a 10 minute flight time.
High temperature materials ideas and strategies are welcome.
Within the HyFly program, DARPA is also addressing how various ground and flight test techniques can be used together to understand hypersonic flight.
Sub-scale HyFly scramjet test articles will be launched from NASA Wallops Flight Test Center, similar to this surrogate launch that took place last fall, to compare subscale flight test data to sub-scale and full-scale scramjet ground test data.
We are very interested in new scaling laws and approaches for scramjet engine flowpaths.

In the area of reusable hypersonics, we have a relatively new program at DARPA called the Force Application and Launch from the Continental United States or FALCON for short.
The ultimate vision of this joint DARPA/AF program is a reusable hypersonic cruise vehicle capability that can carry 12,000 lbs. over a 9,000 nautical mile range in under two hours.
What technologies will be developed and demonstrated in FALCON to enable a hypersonic cruise vehicle by 2025?
We are interested in high temperature materials and thermal management techniques, such as the Hypersoar periodic cruise trajectories, shown here.
We are also interested in aerodynamic configurations that are efficient at hypersonic flight, controllable in low speed flight, and provide a useful mission payload capability.
Advanced guidance, navigation and control systems and effective communication technologies that overcome the difficulties of transmitting and receiving through ionized air are also sought.
Finally, improving propulsion system performance through innovative scramjet and combined cycle engine flow paths is desired; new concepts in this area would be extremely interesting and valuable.

What will be our demonstration strategy for FALCON?
We intend to use a stepping-stone approach, flying expendable "hypersonic gliders" on cheap boosters to provide multiple flight demonstrations, in fact at least one major flight demonstration per year starting in FY06.
The program will design and develop these hypersonic gliders, also known as Common Aero Vehicles, and the cheap boosters, also referred to as Small Launch Vehicles.
The Common Aero Vehicle/Small Launch Vehicle flights will demonstrate technologies such as leading edge and acreage materials, durable thermal insulation systems, guidance, navigation, and control schemes, and perhaps an unpowered periodic trajectory.

A near-term, significant benefit to the Air Force from this FALCON demonstration approach will be the demonstration of a Common Aero Vehicle/Small Launch Vehicle system that could provide a conventional prompt global strike capability from the CONUS in the 2010-2015 timeframe.

I am very optimistic about our future in air-breathing hypersonic flight because we in DARPA/TTO have developed a flight demonstration approach that makes sense and will help focus our technology development during the rest of this decade.

I am also optimistic because I know we are going to get some fantastic ideas from you in the areas of high temperature materials, scramjet propulsion, advanced guidance and control, communications, and aerodynamics.

My hope is that together, we will make this third try at reusable, air-breathing hypersonic flight the charm, and that the glory days of rocket-powered hypersonic flight, the days of the V-2/WAC Corporal, Gagarin and Shepard, and the X-15, will be revisited, albeit this time with a better propulsion system!

Thank you.