The following is a brief essay written by Burt Rutan in 2002 on the Voyager world flight aircraft (http://en.wikipedia.org/wiki/Rutan_Voyager).

Voyager: Small Team, Giant Challenge

Since 1972 when I left my government job testing U.S. Air Force aircraft, I have had the privilege to work with small groups in a true entrepreneurial environment to develop and test over thirty new aircraft types. Of these, the Voyager (which made its historic flight December 14th to 23rd, 1986) was the most rewarding since the challenge involved the globe-circling, non-refueled milestone and the tiny development team was free to make its own rules.

We had to develop an aircraft that could double the world's distance record and we had very limited resources. Our original plan was to obtain funding from a major sponsor and to contract out much of the aircraft's fabrication. When we failed to find a sponsor, we decided to structure a two-phase development program. The first phase, managed by Rutan Aircraft Factory, my homebuilt aircraft company, developed the basic Voyager design and got the prototype into initial flight test. The phase one team was only a few people, including the flight crew, and they worked quickly in secret. The second phase, managed by my brother's company Voyager Aircraft Inc., was responsible for getting the aircraft equipped for long-range flight, testing the refined systems and flying the records. This team, including volunteers, was larger and addressed the many complex disciplines of navigation (in a pre-GPS era), world communication and weather planning. Both phases were financially possible because manufacturers and material suppliers eagerly agreed to donate their products.

For me as a designer, the most rewarding aspect of the Voyager program was the difficult technical challenge. I knew the required range was possible, but it was only achievable by applying our very best efforts. The range of an aircraft is determined by three basic criteria: its propulsion efficiency, its weight and its aerodynamic efficiency. I had to make major improvements in one or more of these areas in order to build an aircraft that could fly more than twice as far as any previous flight. To maximize propulsion efficiency I used engine staging: after the first several days of the trip one engine was shut down so the remaining engine could then operate at a higher, more efficient power setting. This cruise engine was a new water-cooled Continental with 7% better efficiency than the usual light aircraft engine. The primary reason we were able to double the old record related to our success in weight control. By using a new, unusual configuration we could place a large amount of fuel at three spanwise locations: the fuselage and two large booms at 30% of the distance out to the wingtips. A very light main wing and canard wing provided just the amount of structural support for this large fuel mass. The two wings supported the fuel-laden booms via their bending stiffness without depending on the torsional stiffness of a single slender wing. This was Voyager's secret to success. Its graphite composite structure weighed only nine percent of the takeoff weight. The fuel consisted of 73% of the takeoff weight. This phenomenal weight performance was the main reason we were able to achieve our goal of true global range. Regarding aerodynamic efficiency, I was unable to achieve a result as high as a typical sailplane since I was forced to use the unusual configuration and I had to accept the drag of an inoperative engine. The respectable lift-to-drag ratio of approximately 32 was achieved by careful shaping of the wings for laminar flow, avoiding drag-producing protuberances, and careful design of the engine cooling air paths.

The basic specification for the Voyager was changed after the aircraft began its early flight tests in 1984. Originally it was to have more powerful air-cooled engines and was to weigh nearly 11,000 pounds at takeoff, 80% of that being fuel. After we encountered serious undamped structural oscillations in flight at weights above 7000 pounds, I decided to limit the maximum weight to approximately 9500 pounds and to incorporate a new water-cooled engine with better efficiency than the conventional air-cooled types. The aircraft's structural dynamics were risky at the weights we would see during the first two days of the world flight. Merely flying level required a difficult pilot technique or an autopilot with a carefully selected gain that had to be varied as the weight changed during the flight.

The risks we were taking for Voyager's launch on the early morning of December 14, 1986 were high indeed. The aircraft, loaded to a gross weight of 9700 pounds, was 15% heavier than it had ever flown. This new weight would nearly double the runway required at its previous heaviest flight. The structural dynamics were expected to be very bad, maybe even uncontrollable. The crew had been exhausted before from flying the Voyager in turbulence for only a few hours. Now they were to head off over the Pacific with its equatorial storms, and to not land again for more than nine days. In its 2 1/2-year test program of 64 flights totaling 340 hours the Voyager had experienced many systems failures. Several of these resulted in an inability to maintain altitude and resulted in an emergency landing. The flight plan for the world flight was for 225 hours, the vast majority of it over the world's oceans. Most of the time they would be positioned many hours from the nearest airport.

Looking back now at these risks, it is easy to conclude that we should not have attempted the flight. However, in late 1986 we were filled with adrenaline even though exhausted after a five-year research and development program and were thinking of little else except the chance to reach the goal. Today, recalling our activities from the concept layout in 1981 to the world flight in late 1986, the hard part was not the design but the details of building and testing a large, complex aircraft. The job proved to be much more difficult than any of us predicted. Much of that five-year effort involved long hours of hard work from a small group motivated only by the excitement of someday achieving a historically significant aviation milestone.

Our close-knit group operated in an environment that allowed us to revise our ground rules and quickly decide to accept a new risk. This, more than any other factor, was the key to Voyager's success and is the reason that significant new breakthroughs are rarely seen in typical research and development programs. Aircraft development programs are generally operated in an environment in which non-typical risks are not acceptable. That environment would have grounded Voyager and precluded its chances of reaching its goal.


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