

## Making Decisions under Difficult Situations

### **Development of a Russian Rocket Engine for a U.S. Launch Vehicle**

In reflecting upon the catastrophic event that I experienced in the last 6 months, and not really knowing how to share what I feel, and because of the heaviness in my heart, I decided to share one of my project experiences that lasted over a 20 year period.

I was selected in 2010 to be the program manager on the conversion of a Russian booster rocket engine for use on a launch vehicle. I had spent a decade (1993-2003) working with several Russian design bureaus, learning about their technology, and was a member of the team that first examined this rocket engine in Russia in 1993.

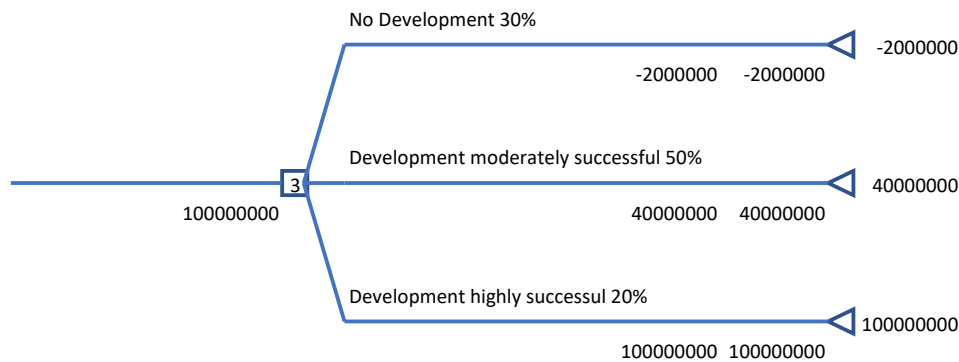
The program was structured to adapt this engine to the first stage of the launch vehicle being built in Ukraine, for a U.S. vehicle prime. New designs such as the engine gimbal system, thrust mount, electronic controls interfaces and actuators, were made as well as the development plan to bring the remaining inventory of rocket engines from Russia was challenging. Included in the planning was a manufacturing plan for this engine to be built in the United States using U.S. materials. Using a pace setting management style with a modern missionary leadership style, the program proceeded smoothly from PDR to CDR. The team was stoked, that they were working on such an advanced technology engine. 40 engines were successfully imported from Russia by the logistics team, and the systems engineers organized and cataloged all the technical documentation including specifications, manufacturing drawings and manufacturing planning. They found a supplier who had the technology to scan and translate the drawings in one pass. The supply chain team selected suppliers for the components such as engine control valve actuators, gimbal actuators and associated electronics, thrust mount and instrumentation. The plan was that all added

parts and material would be U.S. sourced. The test and evaluation team hot fire tested two engines in the U.S. and the test data was analyzed as to whether the engines met their original specification, they did meet the specifications. One was test fired 10 times to assess design margin.

The Challenges ahead were: 1) the uncertainty of the actual condition of all the engines, which 25 years ago had passed their acceptance tests, 2) the effects of uncontrolled storage in terms of corrosion and deterioration, 3) Successfully understanding the interfaces and materials of construction of the mating parts for the U.S components.

The Risks were many: 1) determining the actual costs of the adaptation which would determine the price of the engines, 2) The extent of repairs and costs necessary to allow the engine to meet its specification, 3) The schedule for delivery of engines to meet launch dates, 4) the availability of spare engine parts, to complete the engine, that are no longer in production.

The decision to proceed beyond the Critical Design Review into development and production of engine for the launch vehicle was analyzed as to the risks and rewards and in terms of profit. A program plan was developed to take on and resolve the challenges and risks identified. It was recognized that there still were unknowns that could not be identified initially, so a contingency fund was described. If a decision tree were built, it would have looked like the following:



The plan was presented to management, which approved it even with the 20% success estimate. A proposal subsequently was delivered to the launch vehicle which included the best estimates on risk, cost, and schedule. This amounted to \$100M for the 30-month effort. To deliver the 40 engines and to support them through 20 launches. The vehicle prime gated the funding based upon the critical milestones identified in the proposal. Detailed manufacturing planning was reviewed for the engine conversion, and an enclosed area within the general manufacturing building was identified and secured. Assembly tooling was installed. When fuel leakage was identified in the thrust chamber coolant jacket, a critical decision had to be made to repair, replace, or stop the development. Although I preferred to remanufacture the thrust chamber because of the corrosion effects identified, it was the most expensive. I was outvoted by management and the team proceeded with the repair process. I did not understand this attitude, which in the long run turned out badly for management. It turned out to be more difficult than was initially perceived and cost a lot of time and money to complete. The turbomachinery on the engine was another area where a decision needed to be made to replace all the seals and bearings. This is a considerable effort that was not originally proposed, so a compromised was made, which again I disagreed with. They, upper management, said do just leak checks, and torque checks only. The emotion

generated, around the costs that were mounting way beyond that was planned for. Additional Proposals were made to the vehicle prime for this development phase which was cost plus a fixed fee contract. The initial reaction of the vehicle prime was for us to use our proposed fee. We settled on the vehicle prime picking up some of the costs and the cost to convert a test stand at Stennis Space Center to preform final acceptance tests.

There was a psychological bias in terms of acceptance of a Russian rocket engine in general with writing which was not understood by most people. This was over-come by providing orientation briefings by myself, to explain the engine configuration and explain the engine cycle and how it worked.

The development plan was initially successful, and 8 engines were delivered, and 4 launches were flown from April 2013 to July 2014. The fifth launch exploded shortly after liftoff and was blamed on the engine. However, an investigation showed that the engine ingested foreign material (aluminum particles, and sand). It turned out that the manufacture of the first stage did not clean the fifth stage as delivered; because it was at this time the Russians invaded the Ukraine and annexed the Crimea. The supplier in the Ukraine rushed to get the stage out of the country so that they could get paid. Unfortunately, the vehicle prime also failed to clean the fifth stage like they did on the first four launch vehicles due to the press of time to get the launch off. The vehicle accept that this was their product and that they needed to make sure that the program was successful. The vehicle prime subsequently proceeded to buy another engine program of 60 engines for \$1B-due to concerns over corrosion, aging, and the limited supply of our engine.

**Assignment Grade: A**

**Dr. Xiaomin Yang**

**May 29, 2020**