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On the X-34 FASTRAC – Memorandums of Misunderstanding

Engineers at MSFC designed, developed, and tested propulsion systems that helped launch Saturn I, IB, and V boosters for the Apollo missions. After the Apollo program, Marshall was responsible for the design and development of the propulsion elements for the Shuttle launch vehicle, including the solid rocket boosters, external tank and main engines.

Each of these systems offered new propulsion technological challenges that pushed engineers and administrators beyond Saturn. The technical challenges presented by the development of each of these propulsion systems helped to establish and sustain a culture of engineering conservatism and was often accompanied by a deep level of penetration[i] into contractors that worked on these systems.

Figure 1 FASTRAC engine (NASA)

The FASTRAC Engine Project

In the middle of the 1990s NASA was pushing to lower the cost and development time of access to space. One of the targets to lower barriers to space access was the cost of propulsion systems. NASA sought to prove to itself and to the propulsion community that a new propulsion system could be built much cheaper and much faster than in the past. In fact, the propulsion community within NASA MSFC sought to go from a 'clean sheet' engine design to having the engine in a test stand in 2 years.

The FASTRAC engine project was initiated to demonstrate the feasibility of low cost engine development, give early career propulsion engineers hands-on hardware experience and end-to-end design experience, grow the experience base of propulsion systems engineering, and enable the NASA propulsion community to become a “smart buyer” for future propulsion systems. Commercial, off-the-shelf technologies and common manufacturing methods were adapted to broaden competition and aid in producing lower cost hardware. Development of the FASTRAC engine would institutionalize future rocket development projects and flight hardware procurement activities.

Gas Generator Cycle Engine

Liquid engines can be categorized according to their power cycle, or how power is derived to feed propellants to the main combustion chamber. In a liquid fuel-liquid oxidizer gas-generator rocket cycle, some of the propellant is burned in a small burner called a gas generator and the resulting hot gas is used to power the engine's turbines. The gas is then exhausted. Because the exhaust is "thrown away", this type of engine is also known as open cycle. The cycle is appropriate for moderate power requirements.

FASTRAC Engine

The FASTRAC was a 60,000 lbf thrust, gas generator cycle, Liquid Oxygen and RP-1 (a form of kerosene) engine. A 60,000 lbf thrust class engine was chosen to support a low cost launch vehicle that NASA was studying at the time: the Bantam launch vehicle.

Typically, gas generator cycle engines are much simpler to design and operate than more complex engines such as the Space Shuttle Main Engines. This simpler design was chosen to enable the 2-year goal to get to the test stand. In addition to the FASTRAC engine in-house design, MSFC also initiated a Propulsion System Test Article (PTA) effort. This was an in-house effort to design the propulsion tanks, feed and pressurization systems. MSFC would partner with Stennis Space Center to test the PTA. The PTA was to serve as the ‘backbone’ for the Bantam vehicle.

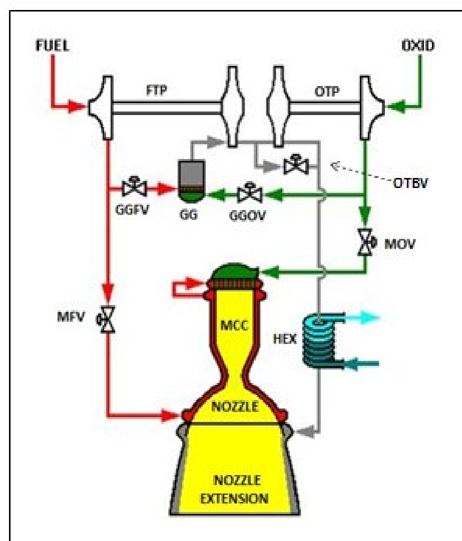

Figure 2 Typical gas generator cycle

X-34 Advanced Technology Demonstrator

At approximately the same time as the FASTRAC engine development, NASA released a NASA Research Announcement (NRA) for a reusable flight x-vehicle to demonstrate technologies, the X-34.

The X-34 Program was part of an effort that began in 1994 to pave the way to full-scale, commercially-developed, reusable launch vehicles reaching orbit with a single stage. NASA’s goal was to reduce payload launch costs from $10,000 per pound on the space shuttle to $1000 per pound. It planned to do so, in part, by finding new ways of doing business such as using innovative design methods, streamlined acquisition procedures, and creating industry-led partnerships with cost sharing to manage the development of advanced technology demonstration vehicles.

The X-34 vehicle was intended only as a flight demonstration vehicle to test some of the key features of reusable launch vehicle operations. NASA selected Orbital Sciences Corporation in 1996, awarding it a fixed price, $49.5 million contract. Under the contract, Orbital was given lead responsibility for vehicle design, fabrication, integration, and initial flight testing for powered flight of the X-34 test vehicle. MSFC was to develop the engine for the X-34.[ii]

A Memorandum of Understanding (MOU) was signed between NASA and Orbital Sciences Corporation in August 1996 to develop the X-34 unmanned reusable space plane as a result of the NRA. FASTRAC was identified as the main engine of X-34. Original FASTRAC objectives evolved to use the engine, which was relatively far along in its development for the then cancelled Bantam vehicle requirements, on the X-34 vehicle under a "use-as-is" clause. X-34 vehicle requirements flow down to the engine continued until project cancellation.

On the Same Flight Path but Not the Same Path

A typical X-34 flight consisted of a drop from an L-1011 aircraft, engine start, acceleration to the planned Mach number and altitude, and a coast phase, followed by re-entry and landing. Aircraft-type elevons, rudder, body flaps and speed brakes provided control and trim during unpowered flight, aided by reaction control during the high-altitude coast phase. Thrust vector control governed pitch and yaw during flight under main engine propulsion.

Figure 3 X-34 Flight profile (http://www.allstar.fiu.edu/prime-tech/flight_profile.htm)

The X-34 Program Structure

The X-34 program structure was complex. NASA Headquarters (HQ) entered in to the agreement with Orbital Sciences to develop the X-34. Originally, the X-34 project was managed from NASA HQ but quickly the leadership transitioned to MSFC and MSFC provided the day-to-day project management. Funding for the X-34 project and the FASTRAC engine came from two separate sources at HQ. This limited the ability to easily transfer funds between the two efforts. Also, the X-34 contract was a fixed price contract. Often times, a fixed price contract creates difficulties with dealing with technology issues that arise during development activities.

It was decided that the MSFC Engines Team would provide engines to the X-34 vehicle contractor as Government Furnished Equipment. The MSFC Main Propulsion System (MPS) Team would provide the MPS design to Orbital through a Government Task Agreement. The MSFC X-34 project manager was responsible for providing project leadership and oversight responsibilities of the overall X-34 project.

In essence, various entities within NASA MSFC served in both customer and sub-contractor roles with respect to Orbital. Orbital had direct contact with NASA HQ, which ultimately funded the program. The complexity of this program structure led to gaps in perception and communication challenges. Pressure to execute the X-34 project was felt by both Orbital Sciences and MSFC team members supporting the effort. One of the X-34 NASA team members provided his view of the project structure (and various product development teams – PDT) in the diagram below.

Project Chronology

- FASTRAC ATP in Apr 1996
- Bantam SRR Jun 1996
- FASTRAC PDR Aug 1996
- MOA with X-34 Aug 1996
- Development engine CDR Apr 1997
- First engine delivery Aug 1998 (ONLY 28 months after ATP)
- First engine hot fire test Dec 1998, last test Dec 2000
- Conducted 57 engine tests in 14 months (facilities unavailable 12 of 26 Months)
- Testing moved from Stennis to Santa Susana Nov 1999, then back to Stennis in Dec. 2000
- Flight engine CDR Jan 2000
- Engine/X-34 integrated fit check Sep 2000
- X-34/MC-1 Projects Cancelled Mar 2001 (Due to 2nd Gen RLV Architecture)

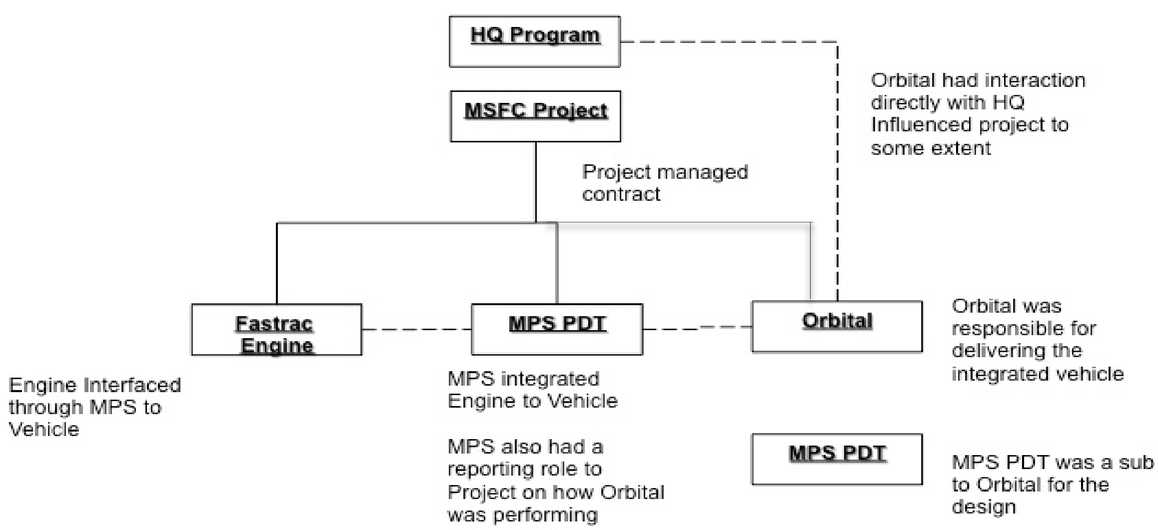

Figure 4 Notional X-34/FASTRAC Organizational Structure

The MSFC engine team believed that they had been directed to offer the engine to the X-34 "as is", which was understood to mean that no vehicle requirements would be flowed down to impact engine development. Through FASTRAC Critical Design Review (CDR), X-34 requirements were not examined in detail. As an example, the X-34 was to be launched in a horizontal configuration, a requirement not initially considered by the engine development team, which tested vertically. Ultimately, concerns arose over the impact of engine orientation on such items as firing the gas generator, engine chill down and propellants and pressurant bleed systems.

Matters Come to a Boil

From a vehicle perspective, it was reasonable to expect that the FASTRAC engine would be modified for the X-34 application. The FASTRAC Engine Manager recalled that the X-34 vehicle team interpreted the agreement with NASA HQ to mean that the FASTRAC was "their vehicle engine". For this reason, the FASTRAC Engine Manager believed that Orbital never acknowledged the "use-as-is" clause in the MOU, and expected the FASTRAC design to meet X-34 vehicle requirements. As a fixed price contract, any changes to the X-34 driven by MPS or FASTRAC engine needs, would cause cost impacts to the vehicle.

The FASTRAC Team faced a similar challenge that any requirements changes threatened their aggressive schedule and goal of demonstrating fast engine development. The MSFC Engine Team believed that any new requirements from the X-34 vehicle would negatively impact the engine design schedule. If they had to redesign along the way to the X-34 then FASTRAC risked looking just like any other NASA development effort which ended up costing more and taking longer than predicted.

The MSFC Engine and PTA Teams operated in a "skunk works" environment. Many sat in proximity to each other, met regularly and developed an esprit de corps mentality. Employees worked very long hours to accomplish both the engine and PTA development. Additionally, some internal processes at the Center, such as configuration management, were not of sufficient maturity to deliver multiple hardware systems, thereby increasing schedule pressure. Against that backdrop, the team also dealt with the change from a technology development program to a flight engine delivery project.

As the projects continued, some personnel felt that there was an "us versus them" mentality between the FASTRAC engine and the X-34 vehicle teams. One engine team member recalled,

> *"[We] resisted all changes we could…if we change our configuration we delay schedule. We really did not care about flying, we wanted to get the engine in the test stand".*

Not all engine team members shared this sentiment however. One recalled,

> *"the team was excited…we were now a flight engine. However, we were overwhelmed. We went from a test bed engine to having to deliver multiple*

> *copies of a flight engine and we were not staffed to do that and some of our processes were not up to speed to accomplish that either. The only reason we were successful is we had a skunk works mentality and mode of operation."*

Personnel on the vehicle side felt the strain,

> *"Each side thought they were on the front of the horse. I don't think FASTRAC even wanted to be on X-34. There was an arrogance there".*

As technical, cost and schedule concerns arose during the development process, Orbital communicated its concerns about the MSFC Team performance to NASA Headquarters. The MSFC MPS Team was criticized for their performance citing schedule delays and conflicts involving system integration. Likewise, the MSFC MPS Team complained that Orbital vehicle requirements were not considered in the delivery dates MSFC engineering was being held to.

The "Memo"

The MSFC MPS Lead wrote an internal memo for record (not to be distributed), documenting his view of the status of the MPS and how requirement changes had impacted the design schedule. Through a clerical error, the memo was accidentally routed to Orbital Sciences, Project Management, MSFC Laboratory Directors, the Center Director, and NASA Headquarters. Many people who read the memo believed that it was critical of the performance of Orbital Sciences.

Make the Call:

1. What led to these problems?
    a. What were some of the underlying issues that lead to problems?
    b. What could have been done differently in setting up these programs?
    c. Are these typical problems encountered in projects and programs today?
2. What is the right size of project to perform in-house? Are supporting systems in place to deliver a single piece of hardware? Multiple copies?
3. Was it fair to expect the MSFC MPS Lead to provide government insight to his management while acting as a subcontractor to the vehicle contractor?
4. You just heard the memo was accidentally distributed to the Contractor. What do you do?
    a. You are the Contractor Project Manager
    b. You are the NASA MSFC MPS Lead
    c. You are the MSFC Project Manager
    d. You are the MSFC Center Director

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[i] Tompkins, Phillip. "Organizational Communication Imperatives: Lessons of the Space Program", Roxbury Publishing Company, 1993, pages 68-69.

[ii] Space Transportation: Critical Areas NASA needs to address in Managing its Reusable Launch Vehicle Program, United States General Accounting Office, June 20, 2001.

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