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Cover Photo: DFR Technologies Delta IV Heavy rocket kit.
http://www.ApogeeEockets.com/Rocket_Kits/Skill_Level_4_Kits/Delta_IV_Heavy_NROL-49

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MX Missile To Peacekeeper The R&D Process Fulfilled

By Mark Burton

What does it take to go from Research & Development (R&D) to Production? In other words, how do you get from idea to a functional rocket? This article examines what is now known as the Peacekeeper Intercontinental Ballistic Missile (ICBM) and its application to model rocketry. Though size and capabilities are different, the process of bringing your design to reality is the same.

Also, in mastering a process, one is equipped to tackle future projects – possibly in a high-paying career. Rocketry is in the news almost daily. From SpaceX Space Station missions to North Korean R&D, rockets have become a permanent part of our lives. That means a lot more space-related career opportunities for a prepared entrepreneur, technician, engineer, or manager. Rocketry is swiftly moving from government (NASA/military) to commercial development. ***Understanding and participating in model and high-power rocketry is a huge step toward a rewarding career in commercial rockets and space exploration.***

R&D starts with an idea. The idea meets a requirement. In the military, requirements are typically based on a threat. In the case of the MX missile, the threat was the Soviet Union. In the 1970s, US intelligence detected the development of a Soviet Multiple Independent Reentry Vehicle (MIRV). That meant the potential destruction of multiple US cities or missile bases. The Cold War philosophy of Mutual Assured Destruction (MAD) demanded equal capability.

On April 4, 1972 the Air Force designated a new Intercontinental Ballistic Missile (ICBM), the Missile-X or "MX." This missile was intended to be a counter-force hard target weapon – a missile silo killer with inherent first strike capability. The inertial guidance system and solid fuel engine technology had already been under development for several years. By 1977 it was decided that the MX would be comprised of three stages powered by solid-propellant rocket motors and a 10 MIRV liquid-fueled fourth stage. The new ICBM would initially be housed and launched from existing Minuteman silos. A mobile basing scheme was later scrapped.

Rocketeer to Missileer

By late 1981 all four stages had been successfully tested on the ground. I graduated from the University of Illinois in May 1981 with a degree in Aero/Astro Engineering. A month later, I was a newly commissioned Lieutenant assigned to Vandenberg AFB for initial testing of the MX missile – the biggest ICBM ever built.

A launch pad for the space shuttle (SLC6) was also under development and I asked to be reassigned to the space shuttle project. My commander gave me some wise advice. Though he didn't know the space shuttle project at Vandenberg would eventually be scrapped, he convinced me that building and launching the MX would be very rewarding. He was right.

SLC6 was operational in 1985 (the year I departed Vandenberg) and the first space shuttle launch was planned for 1986. The Challenger disaster in Jan 1986 grounded the shuttle fleet. The Air Force eventually terminated the space shuttle program at Vandenberg in 1989 without a single launch. The estimated cost for the discontinued program was $4B. It's amazing how events and decisions are connected.

You can't beat the roar of a successful launch. In the case of the Peacekeeper missile, there was a whoosh instead of a roar. That's because hot gas ejected the missile from a canister to an altitude of about 80 feet before the first stage ignited. After ejection, everyone tensely watched as a 200K pound rocket hung in the sky until the first stage lit. You can see and hear a Peacekeeper launch at YouTube (www.youtube.com/watch?v=zCSoN1tqmgU&NR=1). Very spectacular. A similar effect can be obtained for model rockets from piston launchers, as discussed in Apogee *Peak of Flight Newsletter* issue 47 (www.apogeerockets.com/education/downloads/Newsletter47.pdf). The hot gas is generated from the model rocket engine rather than a separate hot gas generator, but the effect is comparable. Piston launchers in model rocketry allow the elimination

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of launch lugs. Though "hot gas" was used to eject the missile, it was a comparably "cold launch" considering the destructively high temperature of first stage ignition. Cold launch, used on US submarine missiles and Soviet SS missiles, allowed the rapid reloading and reuse of silos for multiple launches, compared with the fiery launch of a Minuteman missile (http://www.youtube.com/watch?v=Rc6iDrA8F2U).

The Peacekeeper is protected inside the canister by Teflon-coated urethane pads. Nine rows of pads are used to protect and guide the missile smoothly up and out of the canister. The pads fall away when exiting the canister. The cold launch system uses a reinforced steel canister to house the missile. At the bottom of the canister is a Launch Ejection Gas Generator (LEGG). A small rocket motor is fired into 130 gallons of water contained in the LEGG reservoir. This creates steam pressure that pushes the Peacekeeper up and out of the canister prior to first stage ignition.

I was a launch officer on the first eight Peacekeeper launches at Vandenberg AFB in the early eighties. In retrospect, it was amazing that all test launches were successful.

There was, however, an early weld failure during launch pad integration. Though the MX was planned for launching out of Minuteman Silos, the first eight test launches were conducted from the surface. Contractors constructed a tower on a concrete launch pad that could be lowered to load the missile and erected to launch. However, when raising the inert test missile, tower welds cracked and the entire assembly crashed into the pad. The nose was destroyed and a large chunk of concrete was displaced as missile contacted hard surface. This is the purpose of testing. Had this been a live missile, the failure would likely have been catastrophic.

With the largest ICBM ever constructed, assembly, prep, and launch were accomplished very methodically considering the ~$50M price tag per missile. Compare that to the cost of your favorite rocket. Perhaps if you got enough sponsors …

Wisdom to Look Ahead

Good development looks ahead to all possible options. This saves time and money. Politics hammers out a compromise between capability and cost but also introduces variables. What is good for one administration and threat environment may be inadequate for the next. So a project lasting decades (R&D, production, deployment, and maintenance), may require modifications. If significant enough, the entire design might be scrapped in favor of a more cost-effective option.

US nuclear strategy depends on several assumptions. As its name suggests, the Peacekeeper was primarily a deterrent. It was developed for the intended purpose of counterforce strikes. Requirements for the MX were based on assumptions of quantity, intensity, and location. The MIRV concept greatly increased the potential delivery of hostile nuclear weapons. For every missile the Soviet Union launched, ten cities or missile bases could be destroyed.

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At the time there was little capability for missile defense – which was also part of the strategy. Both nations were equally vulnerable to missile attack so weapon systems were equally effective.

Techs carefully integrate RVs to the deployment ring. RVs are individually released while in orbit.

What size warheads can the enemy deliver? Special Weapons (http://en.wikipedia.org/wiki/Armed_Forces_Special_Weapons_Project) technology dictates the weight to yield ratio of a warhead and the corresponding range of the missile. An early Redstone could deliver a 3.5MT nuclear warhead 57.5 miles or a 500KT nuclear warhead 201 miles. Really, would you want to be 50 some miles from a 3.5MT nuclear explosion? A single ICBM reentry vehicle (RV) is on the order of 300 KT (300,000 tons of TNT). That's about 14 times the explosive energy of Fat Man detonated over Nagasaki.

The final assumption is location. If the USSR targeted American cities, should the US target USSR cities as a viable deterrent? These issues have been integral to treaty negotiation. Check out the Federation of American Scientists Nuclear Information Project for a fascinating study of Soviet/Russian ICBM history (www.fas.org/nuke/guide/russia/icbm/index.html). Now, as additional nations develop nuclear capable ICBMs, the world figuratively holds its breath, waiting for the first use of nuclear weapons in 70 years.

MX RVs reenter the atmosphere from orbit over the Kwajalein Test Range.

Requirements for Mission Capability

Requirements led to mission capability. Accuracy and

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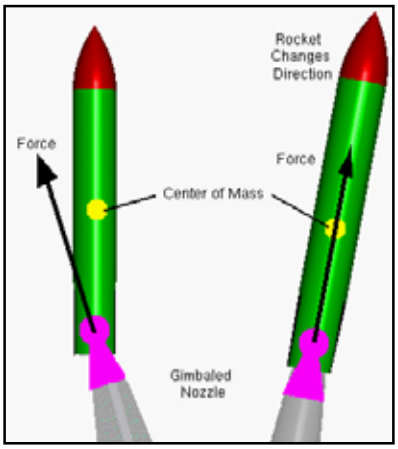
reliability were key factors in MX development. During testing on the Kwajalein Test Range (www.smdc.army.mil/RTS.html), RVs were able to hit an area the size of the Pentagon courtyard – an amazing accomplishment considering they were launched from the central California coast. Each missile had a warhead with the ability to deliver up to ten individual warheads, which meant that 50 active Peacekeeper missiles could destroy up to 500 enemy missile silos. The Peacekeeper had a range of 6,000 miles and a speed of 15,000 mph.

Where Are The Fins?

Among the differences from model rocketry, besides a "cold launch," the MX did not use fins for stability. This significantly reduces drag (proportional to the square of velocity) but increases complexity. A gimbal motor is the key component in finless flight. Instead of adjusting the rear of the rocket with three or four fins during flight, servos position the angle of the motor to guide the rocket (see *Peak of Flight Newsletter* #248 at: www.ApogeeRockets.com/education/downloads/newsletter248.pdf). For a large rocket (liquid or solid fuel), this means a ball (gimbal) at the base of the nozzle allowing motion in two axes (http://exploration.grc.nasa.gov/education/rocket/gimbaled.html).



Model rocketry has imitated this technique by adjusting the angle of the motor (www.ukrocketman.com/rocketry/gimbal.shtml). A more recent example is a video circulating among model rocket clubs where a platform actually hovers in the air and descends to a controlled landing (www.youtube.com/watch?v=orUjSkc2pG0). An ARS member said "We could build one of those! Maybe..." A gimbal nozzle system achieves stability by sensing vertical orientation and pushing the nozzle with x-y servos. The closed-loop system must sense attitude changes and servos must react quickly enough to keep the rocket moving in the desired direction. This is also useful for orbital insertion (requires special permission for model rocketeers).

With the miniaturization and simplification of microcontrollers and robotics, a model rocketeer today has the resources to do what was limited to governments and scientists in the 1960s. Examples of common microcontrollers are the PIC, Arduino, BASIC Stamp, and TI MSP430 (www.societyofrobots.com/microcontroller_tutorial.shtml). Even kids today are learning and applying the technology of robotics using Lego Mindstorms, the robotics version of Legos. Combined with rocketry, this technology opens doors to a multitude of possibilities. The reduction in size and increased accuracy of gyro sensors (http://learn.parallax.com/KickStart/27911) completes the control system for finless flight in model rocketry.

Where to Put the MX?

Basing was always a political hot-potato for the MX, seriously affecting design and deployment. The MX launch canister barely fit the Minuteman silo. But what if new silos were built specifically for MX? On 22 Nov 1982, the administration proposed the Dense Pack scheme (and also changed the MX's name to "Peacekeeper"). This involved building super hard silos (>10,000 psi hardness) only 1800 feet apart, the idea being that "fratricide" among a wave of attacking warheads (the tendency of nearby nuclear explosions to damage other warheads) would allow a substantial

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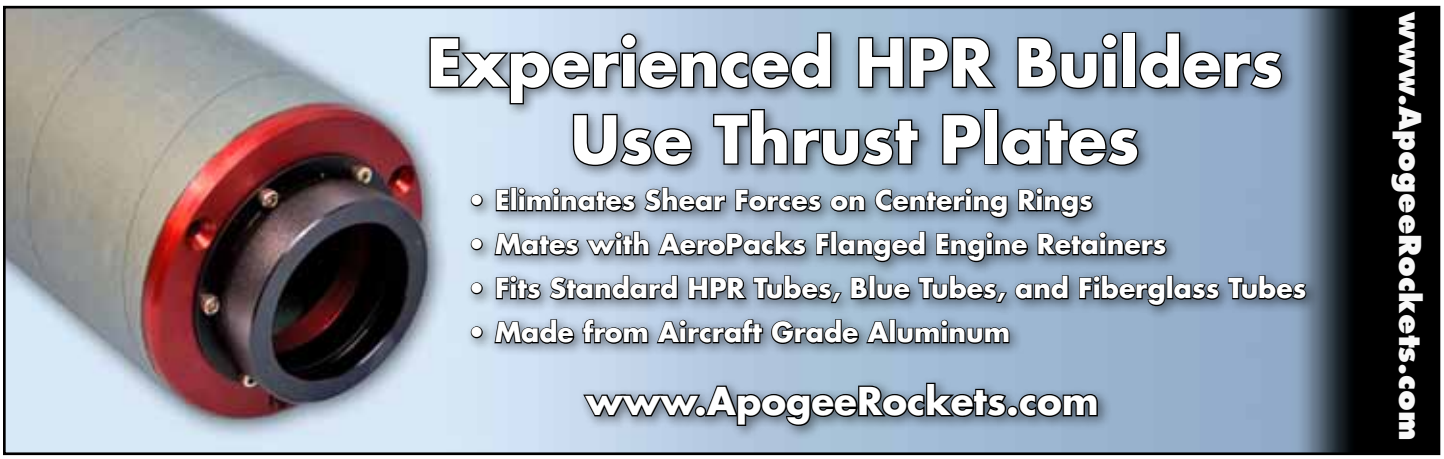

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Peacekeeper nose assembly

Bottom of nose assembly showing RV mounting points

Stage 4 (Rocketdyne)

portion of the force to survive, which could then be launched before the next wave arrived. However, assumptions were questionable and Soviet technical improvements could totally defeat it (like using terminally guided warheads). In the end, the great basing mode saga wound down with the Reagan administration proposing that the MX simply be emplaced in existing Minuteman silos in April 1983.

Fifty operational missiles were deployed 1987-1988 to F.E. Warren Air Force Basse in Wyoming into modified Minuteman silos. Congress limited the deployment Peacekeeper ICBMs to 50 missiles until a more survivable basing plan could be developed. A "rail garrison" basing system was proposed using 25 trains, each with two missiles, on the national railroad system for concealment. Rail Garrison was scrapped due to budgetary constraints and the changing international situation. I was offered a position on the Rail Garrison team but declined.

The Peacekeeper project cost around $20B, producing 114 missiles, at about $45M each. Fifty missiles were test launched in California by a missile combat crew for training. Peacekeeper missiles were

Stage 4 fuel tanks and gyro

Stage 3 – 65,000 lbs thrust (telescoping nozzle) (Hercules)

Stage 2 – 275,000 lbs thrust (Aerojet)

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Stage 1 – 500,000 lbs thrust (Thiokol)

gradually retired. Crews removed about 17 missiles a year until the last Peacekeeper was removed from alert on 19 Sep 2005 during the final deactivation ceremony when the 400th Missile Squadron inactivated as well. Orbital Sciences converted the rockets to a satellite launcher (OSP-2 Minotaur IV SLV) and warheads (MK21/W87) were deployed on existing Minuteman III missiles or stockpiled at Sandia National Labs.

The National Museum of Nuclear Science and History in Albuquerque, New Mexico (www.nuclearmuseum.org) received a Peacekeeper missile in April 2011 (without the launch canister). The 71-foot, 195,000 pound LGM-118A missile arrived in sections and can be viewed on the back lot. Re-assembly for a completed exhibit may takes years (www.kirtland.af.mil/news/story.asp?id=123253861).

"This significant object will be one of the largest items in our already-extensive collection," said Jim Walther, director of the museum. "This is believed to be the last of these artifacts available for public display. The museum is fortunate to receive and preserve it for future generations."

Seeing the missile stages again brought back great memories of four years at Vandenberg AFB. Control facilities, assembly buildings, transport vehicles, and a launch pad formed the network of resources necessary to test launch a missile of this size. In addition to the missile itself, leading edge technology was used in the early 80s to collect ground data and air telemetry. Facilities were connected by fiber optic cables for high speed data transmission.

Guidelines for Development

• Make a list of requirements (what you want your rocket to do), and your budget.

• Run the numbers. Get some good software like RockSim Pro (www.apogeerockets.com/Rocket_Software/RockSim_Pro/RockSim_Pro_v1_CD) to test your ideas. It will save a lot of time and money later on – very important in commercial project management.

• Look ahead to all aspects of your design – construction, integration, payload, propellant, launch, recovery, reuse, transportation, etc.

• Research what components you can use "off the shelf" (commercially available).

• Investigate the science/technology for future component availability.

• Test individual components and their integration into the system. Use the scientific method – hypothesis, test, analysis.

• Safety first – if it looks hazardous, it probably is – take precautions.

• Don't give up. If something doesn't work, try something else. Thomas Edison failed thousands of times before he revolutionized the world by inventing and patenting the incandescent light bulb.

• Find a buddy or team to share ideas (synergy).

• Find a mentor at a local school or business.

• Know the technology – manufacturing, materials, electronics, and software.

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• If you're short on funding, look for sponsors (if you're not short on funding, send me some $$$).

• Participate in local science events to sharpen your skills.

About the author, Mark Burton

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• BS – Aero/Astro Engineering, Univ of IL
• MS – Systems Engineering, Wright State Univ
• USAF
… MX (Peacekeeper ICBM) R&D (1981-1985)
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… Retired Major (1999)
• High School Science & Technology (1999-present)
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