

## **Nuclear Thermal Rocket (NTR) Development Risk Communication**

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There are clear advantages of development of a Nuclear Thermal Rocket (NTR) for a crewed mission to Mars. NTR for in-space propulsion enables more ambitious space missions by providing high thrust at high specific impulse (~900 sec) that is 2 times the best theoretical performance possible for chemical rockets. Missions can be optimized for maximum payload capability to take more payload with reduced total mass to orbit; saving cost on reduction of the number of launch vehicles needed. Or missions can be optimized to minimize trip time significantly to reduce the deep space radiation exposure to the crew. NTR propulsion technology is a game changer for space exploration.

However, “NUCLEAR” is a word that is feared and vilified by some groups and the hostility towards development of any nuclear systems can meet great opposition by the public as well as from national leaders and people in authority. Communication of nuclear safety will be critical to the success of the development of the NTR.

Why is there a fear of nuclear? A bomb that can level a city is a scary weapon. The first and only times the Nuclear Bomb was used in a war was on Hiroshima and Nagasaki during World War 2. The “Little Boy” atomic bomb was dropped on Hiroshima on August 6, 1945 and the “Fat Man” on Nagasaki 3 days later on August 9<sup>th</sup>. Within the first 4 months of bombings, 90-166 thousand people died in Hiroshima and 60-80 thousand died in Nagasaki. It is important to note for comparison that over 500 thousand people died and 5 million made homeless due to strategic bombing (~150 thousand tons) of Japanese cities and war assets with conventional non-nuclear

weapons between 1942-1945. A major bombing campaign of “firebombing” of Tokyo called “Operation Meetinghouse” on March 9 & 10 consisting of 334 B-29’s dropped ~1,700 tons of bombs around 16 square mile area and over 100 thousand people have been estimated to have died. The declaration of death is very clear for conventional weapons and then the declaration of death due to radiation becomes vague and unclear. This may have been due to people misunderstanding the dangers and effects of radiation when assessing the damage and harm to people initially, but it is also become insidious when expressing opposition to nuclear energy.

A nuclear radiation accident can be scary due to the power involved and the fear of radiation release. The International Atomic Energy Agency defines a nuclear and radiation accident a “an event that has led to significant consequences to people, the environment or the facility.” There have been 3 commercial nuclear reactor accidents (Chernobyl, Three Mile Island, and Fukushima) that stand out to the public and much of the information about the result and impact to workers, environment, and public can be misleading. Often information is presented without clear correlation with radiation and other pertinent information is left out presenting a very scary situation to affect the emotions of the reader. A very boring but “critically acclaimed” movie was made in 1979 called “The China Syndrome” starring Jane Fonda and Jack Lemmon. The film was released on March 16, 1979, 12 days before the 3-Mile Island nuclear accident in Pennsylvania. The basis from the movie was from a few nuclear plant incidents and in particular, the Brown’s Ferry Al-

abama Power Plant fire. In one scene from the movie, a physicist Dr. Elliott Lowell played by Donald Hotton states that a China Syndrome event would make “an area the size of Pennsylvania” permanently uninhabitable. Real serious nuclear incidents like Chernobyl and Fukushima are often cited to make people fear the consequences of using nuclear power. However, the consequences are at best poorly communicated and at worst fictitiously inflated to instigate social unrest against nuclear power. There is an article being circulated on Facebook with a title “28 Signs that the (US) West Coast is being absolutely fried with nuclear radiation from Fukushima” which focus on mis-information and fear mongering.

Nuclear power and NTR are powerful resources that can open many doors for future prosperity and capability. With great power comes great responsibility. Radiation and its effects need to be better understood, quantified, and communicated. A human mission to Mars has its own risks of deep space radiation and is considered a considerable risk at 400 milli-Sieverts per year in deep space and 245 milli-Sieverts per year on the surface of Mars as measured by the Mars Curiosity mission. Although these quantities of ionizing radiation are within the astronaut career limit, it exceeds the yearly average amounts of ionizing radiation. Astronaut crews have experienced these levels of radiation before, but for durations shorter than a year, and a mission to Mars could possibly be 3 years in length. There is also evidence that people can comfortably handle higher levels of ionizing radiation where the radiation occurs naturally like Ramsar, Iran when people can experience 270 milli-Sieverts per year.

A risk posture that the development, test, and flight of an NTR will meet opposition from groups who oppose nuclear energy must be likely and the impact can be severe to the ef-

fort. Active risk mitigation must be taken for an NTR full-scale development project. The NTR design must take into account safety for transport and off nominal conditions. Nuclear fuel element must consider containment of fission products and Low Enriched Uranium (LEU) that may meet less opposition should be considered for safety and security reasons. Even though testing was conducted on Rover/NERVA safely and successfully in the 60's with exhaust sent heavenward in to open air, modern testing of NTR must consider full containment and no release of ionizing radiation to the public and must meet the current requirement of no more than 0.1 milli-Sieverts per year to the public. 0.1 milli-Sieverts is equivalent to eating one banana or a 20 hour plane flight. Good communication with the public and regulatory agencies will be essential to show that all effort is applied toward protection to the public and astronauts. The inspiring endeavor to put humans on Mars to study the planet, search for life, and learn more about this Solar System will be full of risks but it will be worth it. NTR will be worth the development effort if it allows humans to explore our Solar System.