2011 Nuclear and Emerging Technologies for Space

Technology for Major Renewed Space Exploration

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I feel honored and privileged to be with all of you at this very important 2011 Nuclear and Emerging Technologies for Space meeting. I thank Shannon Bragg-Sitton and Mike Houts for this honor and assignment and especially for their work in organizing this meeting. I view this very much as a regeneration and broadening of the Symposia on Space Nuclear Power Systems that started in 1983 and continued into the 2000's. Those were led by Nils Diaz and Mohamed El-Genk with Mary Bragg as the hands-on operations leader. I consider such sessions extremely important now especially in view of the serious economic situation our country is facing that adds significantly to the lack of clear definition of the direction of our space and aeronautics activities. So I thank all of you who have generated this NETS activity very, very much.

We do have to recognize that our very limited current economic condition certainly restricts our national ability to move actively in many of the areas that are important to assuring our continued leadership in the development and execution of major space exploration activities. And that also reduces the stimulus that the space program has provided for our young people to enter into science and technology areas and activities that enhanced our national capabilities and standings. The lack of clear definition of our space mission objectives certainly limits our work on required research and technological development to achieve desired exploration capabilities. I, therefore, have serious concerns about the course of our space and also aeronautics activities and our resulting international standing in these areas as we move forward. I believe it is especially important to have effective deliberative sessions such as this to strongly express our concerns while also providing the full discussion of the capabilities, research, technology developments and potential mission objectives that are required and that should be pursued to assure that the US retains its broad international leadership on a continuing basis. So I very much welcome this regeneration and expansion of the SNPS in these NETS sessions to provide discussion and presentation of ongoing activities with identification of promising future activities and goals.

As we hear of major ongoing activities, it is also necessary to recognize the major program accomplishments that have been achieved and that should be recalled and further updated and advanced with currently available technologies that can provide us great capability to achieve future space mission objectives. In that context, I have been asked to review the work that we accomplished in the development of nuclear rocket propulsion back in the 1960's that provided a capability for deep space exploration but that was never mission applied. I am referring to the accomplishments of the old Rover program, with its KIWI and Phoebus reactors, and the NERVA engine development. I sincerely believe we developed and demonstrated in that program that back in 1970 we were prepared to start planning for early human exploration to deep space including Mars. We've been on hold ever since even though some further very limited research has continued.

The nuclear rocket propulsion work had actually been started in the 1950's at the Livermore and Los Alamos Laboratories of the Atomic Energy Commission but it was narrowed down to Los Alamos while Livermore went on to nuclear ramjet development with both programs under the overall management of a joint office of the Air Force and the AEC. When NASA was established on October 1, 1958, a Presidential Executive Order was issued transferring responsibility for the nuclear rocket propulsion development from the Air Force to NASA. I was immediately assigned as the NASA man working with the Air Force and AEC office during the transfer process. However that very contentious transfer process led by the NASA Administrator Keith Glennan and AEC Chairman John McCone and involving key members of Congress including Clinton Anderson and also the Air Force Colonel heading the program extended until August 31, 1960 when a new AEC-NASA joint office, which was later named the AEC-NASA Space Nuclear Propulsion Office, was finally announced. I was named Manager and Milton Klein, who had been at the AEC's Chicago Operations Office, was brought in and named Deputy Manager.

The organizational agreement established that the AEC would fund the required reactor development work and NASA would fund development of the non-nuclear elements and the integration of the reactor into the full rocket engine and vehicle system. The organization was made up of members of NASA, the AEC, and members of the AF group that had been leading the program previously. We very quickly brought all the involved groups together and initiated actions aimed at moving from the very important Los Alamos work on the graphite reactor for the nuclear rocket propulsion to full engine system development and even to flight test systems. (Figure 1) That brought Aerojet-General and Westinghouse in for the NERVA engine development, Lockheed to develop a rocket flight test system using the NERVA engine, and we also expanded the test facility capabilities in Nevada to include multiple reactor tests and full engine system testing.

At that early time, Los Alamos had already been actively working on its graphite based KIWI reactors (Figure 2) and two of them had each already been briefly tested for about 5 minutes at about 80 megawatts (MW) of power in the first test cell at Jackass Flats in Nevada. These tests were run with gaseous hydrogen and the first one had no corrosion protection on the fuel elements. Here (Figure 3) I am with some of the key Los Alamos people and staff who were responsible throughout the program for their outstanding accomplishments --- Norris Bradbury, Raemer Schreiber, Rod Spence, Keith Boyer, Frank Durham, and others. Their leadership and accomplishments in these graphite reactor developments were outstanding. They moved on to developing and testing several KIWI-B reactors that were designed for 1000 Mw to achieve 50,000 pounds of thrust using liquid hydrogen leading to the KIWI-B4A (Figure 4) with a niobium carbide coating protection on the fuel elements. That preferred design was tested on November 30, 1962. Flashes of light in the nozzle exhaust quickly indicated serious core damage as the power went over 250 Mw so the test was shut down after several seconds.

A week later, on December 7 (Figure 5) President John F. Kennedy and Vice-President Lyndon B. Johnson visited Los Alamos and the next day, the President flew to the NRDS in Nevada to visit the test site and review the whole program. A large entourage was with the President at both sites including Senator Clinton Anderson, Cong. Morris, Glenn Seaborg, Jerome Wiesner, Robert Seamans, McGeorge Bundy, Pierre Salinger, Harold Brown, James Ramey, Dwight Ink, and others. It was apparent during those visits with the President that with the possible exception of Jerry Wiesner, the President's Science Advisor, work on the nuclear rocket propulsion would be well supported. It was certainly an exciting and very encouraging meeting.

However at that time, we still did not have an understanding of the cause of the KIWI-B4A failure. So after that gathering, I called a meeting of the key members of our SNPO and Los Alamos team, representatives from the NASA Langley and Lewis Labs and the Marshall Space Flight Center to review the status of the program. I made and expressed my decision then that we would have no further hot testing of a full reactor until thorough work was done to identify the causes of the problems and develop clear solutions. With some objections from Dr. Bradbury, we went through comprehensive component, subsystem, and vibration testing, with all participants involved, including a full cold flow, non-fissioning, system test that clearly showed that the problem was the result of Los Alamos having placed a peripheral seal around the inlet of the reactor core so that the low exit pressure surrounding the large cluster of graphite fuel elements permitted interstitial flow between those fuel elements causing those elements to vibrate and fail. Westinghouse had already been working on bundling the core to reduce interstitial flow corrosion of the elements and had placed the seal of the NERVA reactor at the exit and was working on even further increased lateral support.

From then on, (Figure 6) with our very extensive testing, things improved. Los Alamos got back to very encouraging and successful KIWI reactor testing and on to the Phoebus reactors operating up to 4200 Mw. Aerojet and Westinghouse NERVA reactor tests started in 1964 including one with full power operation at 1100 Mw for 62 minutes on December 13, 1967 and a full 1100 Mw NERVA XE engine test in 1969. (Figure 7) That engine of over 50,000 pounds of thrust concluded our testing after it was run for four hours with 28 starts. The flight test program had been previously killed for budget reasons in 1965.

Yes, we did develop and had demonstrated the nuclear rocket propulsion system that could move us forward to substantial deep space missions starting in 1970 --- 40 years ago. So here are some of the mission analyses we did for these well proven nuclear propelled rocket systems showing the benefits they would provide. Here (Figure 8) is the comparison of payloads achieved by the nuclear third stage on the two stages of the Saturn V vehicle compared to the chemical third stage. A good fifty percent increase. Here (Figure 9) is the comparison of the Earth-orbit weights required for a round trip manned Mars mission we were thinking of in the mid 60’s for various launch years using a nuclear or a chemical upper stage system. Needless to say, we did major mission analyses and I am sure you are not at all surprised to find such significant benefits with the nuclear rocket propulsion.

So let’s get back on the proven technology development we did 50 years ago and advance it further with updated technology to build a truly versatile, secure space exploration capability to maintain and grow our leadership.