NUCLEAR CRYOGENIC PROPULSION STAGE AFFORDABLE DEVELOPMENT STRAGETY. G. E. Doughty[1], H. P. Gerrish[2], R. J. Kenny[3], [1]NASA, Marshall Space Flight Center, ER24 MSFC, 35812, glen.e.doughty@nasa.gov, [2]NASA, Marshall Space Flight Center, ER20 MSFC, 35812, harold.p.gerrish@nasa.gov, [3]NASA, Marshall Space Flight Center, ER42 MSFC, 35812, robert.j.kenny@nasa.gov.

Introduction:

The development of nuclear power for space use in nuclear thermal propulsion (NTP) systems will involve significant expenditures of funds and require major technology development efforts. The development effort must be economically viable yet sufficient to validate the systems designed. Efforts are underway within the National Aeronautics and Space Administration's (NASA) Nuclear Cryogenic Propulsion Stage Project (NCPS) to study what a viable program would entail. The study will produce an integrated schedule, cost estimate and technology development plan. This will include the evaluation of various options for test facilities, types of testing and use of the engine, components, and technology developed. A "Human Rating" approach will also be developed and factored into the schedule, budget and technology development approach.

A Concept of Operations (Con-Ops) has been developed that takes into account the approach, and uses as a springboard, what was done in the Rover/NERVA Programs, the collective resources of NASA and the Department of Energy and combines them in a cost effective manner. The Con-Ops starts at the component level and moves through complete engine verification and validation. It will take into account, when completed, Technology Readiness Levels (TRLs), contracts needed from the beginning to end of the program, construction of facility cost, civil servant manpower estimates, the flow of data and information and money at all external programmatic interfaces. A reasonably accurate set plans can be made by using triage, adequate margins (both programmatic and technical), and by employing field experts who understand the relationship of the Key Driving Requirements (KDRs) to the choice of margin as it relates to the sensitivity and impact to the system performance, schedule and budget.

A Preliminary Con-Ops was developed by first determining the overall functional activities that take place in order to design, develop, and test nuclear rockets. This was then translated into a Work Breakdown Structure (WBS) for those activities. The possible solutions in the list can then be traded, one against the other. Different solution sets may be put together, and the level of acceptable risk compared through the lens of cost and schedule. The best Con-Ops would then be the one with the best balance between programmatic and technical risk, schedule and budget.

Special attention in developing the Con-Ops has been, or will be in the case of the incomplete portions of the study, paid to the accurate identification of low TRLs. At each level of the engine, stage, and supporting infrastructure a survey of the TRLs as they relate to use in a nuclear engine and vehicle have been, or will be made, by experts in the given area. Each technical specialty will identify the areas where the current TRL is inadequate to preced into the design phase.

Another key to developing a good program plan is accurate identification of requirements as well as what is required for validation of that set of requirements, especially as they relate to "Human Rating." Validation activities, especially at the engine and stage level will drive infrastructure costs. Validation at the component level can drive contract costs and often become critical items in the development schedules. Development of facilities and the number of tests performed will directly correlate with the TRL levels of the system and its components. The lower the TRL and the more challenging the design, the more test-fail-fix cycles will be required. The development portion of the testing is often underestimated. Methodologies have been developed based on TRL, design complexity, and team experience that estimate the amount of development testing that necessary to resolve unforeseen problems and validate the resulting engine and stage design. These factors will be a fundamental part in developing the schedule, budget and design solutions for this study.

In a related NCPS effort, an Nuclear Thermal Rocket (NTR) engine design activity is being performed. The design activities for FY 14 include thermal modeling, cycle layout, actual design layout to a top tier drawing level, engine component requirements and layout, and detailed design of the reactor/chamber assembly. The current design requirements include a thrust of 25k lbs with 900 seconds of specific impulse. Mars Mission Simulation Studies at Marshall Spae Flight Center by the Advanced Concepts Office have shown that a three engine cluster at these thrust and Isp levels will successfully perform the mission. Also, as part of the engine design activity, a man-rating requirements approach will be explored. This approach will include design life criteria, material characteristics approach, material life in the proximity of a nuclear reactor as a function of time, and design margin. The presentation will include design activities for the engine and the 2014 schedule of activities.

References:
None