Overview of the Orion Thermal Protection System Advanced Development Project

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ABSTRACT
The Orion Thermal Protection System (TPS) Advanced Development Project (ADP) was motivated by a clear need to develop a viable ablative material for the Orion heat shield. The reusable TPS materials, such as those used for the Space Shuttle, were inappropriate for the Orion since the maximum heating for Orion lunar returns was expected to exceed those for the Shuttle by at least a factor 5. For these higher heating applications ablative systems are considered the only alternative. However, prior to the start of the Orion TPS ADP, NASA's in-house R&D on ablative TPS materials had spent more than four decades in a state of neglect – focusing more on re-usable systems such as those employed on the Space Shuttle. Furthermore, the industrial base for ablative TPS materials had essentially collapsed. After decades of no new work from NASA, and only an extremely limited effort by the DoD, the TPS material providers simply had no customers. To address these problems, drastic action was necessary to reinvigorate the industry while simultaneously adjusting our in-house workforce to meet development challenges. The TPS ADP was thus commissioned as a three year, mission focused, technology development project, entrusted with the sole responsibility of maturing a viable Orion heat shield TPS material and integrated design.

The presentation will provide the history and outcomes of the three-year Orion TPS ADP. The discussion will include the initial materials, as well as the phased down-selection process leading eventually to the final Avocat TPS solution for Orion. Presentation shall also attend to the schedule and programmatic challenges presented by the TPS ADP. Not only was it necessary to perform TPS materials research, but it was also necessary to adhere to a strict schedule and perform heat shield preliminary design work specific for Orion. The TPS ADP was given the responsibility to perform the DDT&E work related to all aspects of the heat shield, including: TPS materials, carrier structure, and integration and attachment with both the Crew Module and the Service Module. So while the Project was working with multiple vendors on multiple material options, it was simultaneously developing heat shield structural designs and TPS architecture strategies that would allow the various TPS options to scale up to a 5 meter heat shield. In fact, it was recognized from the beginning that one of the most significant challenges of the TPS ADP was developing a viable manufacturing, assembly and integration strategy for the large acreage heat shield.

A focused assessment will also address the number of and type of tests that were necessary to advance the technology readiness of the various materials under consideration. Such information is informative towards future TPS development activities for both Science and Exploration missions. Several serious technical problems were accounted with every material system. In some cases these problems were related to material performance or manufacturing, however, in other cases the problems were encountered due to scale-up or integration challenges. The specific challenges that were most problematic as well as those likely to occur in other TPS / heatshield development efforts will be covered in detail.

Finally, the intensive TPS development activity and the maturation of multiple ablative TPS materials paid significant collateral benefits. Not only did the TPS ADP succeed in providing the Avcoat system for Orion, but due to the Project's intensive development of both PICA and Avcoat, the Project also significantly contributed to the heat shield TPS solution for the NASA MSL Mars entry capsule, and provided critical TPS material and heat shield design data for the SpaceX Dragon capsule.