# Critical Initial Flaw Size of the Upper Stage Simulator Welds for the Ares I-X Launch Vehicle

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Ares I-X flight test vehicle consists of a live first stage and a mass-consistent simulated second stage and payload. The inert upper stage, the Upper Stage Simulator (USS) is comprised of several cylindrical segments formed by rolling and welded A516 grade 70 structural steel ½-inch sheet. A flange is welded onto the top and bottom of each segment. The segments are bolted together at their flange interfaces during assembly of the USS.

While the vehicle is not a human space flight vehicle, human space flight requirements were voluntarily chosen for application to the Ares I-X Upper Stage. Since the flange-skin welds are in the primary load path of the vehicle, the integrity of the welds is of critical importance. A critical initial flaw size (CIFS) analysis was performed for these welds. The CIFS will be used to define the quality control requirements and inspection criteria during manufacturing

A NASGRO fatigue analysis was performed to analytically determine the maximum weld defect size and shape that would not become critical after four simulated life cycles. In order to perform this analysis, several inputs were required including cyclic stress, mean stress, crack growth rate data and weld fracture toughness properties. Where necessary independent analysis and testing were developed to determine appropriate input values necessary in these CIFS analysis. Important material properties of the specific weld were deemed process dependent and hence independent testing was performed to determine the properties. Selected material property tests were performed on the parent material to verify that its material properties fell within the range of published data.

First cyclic and steady state load cases based upon manufacturing, assembly, ground handling and launch environment were determined. The loads were then applied to critical segments of the USS. Finite element analyses of these segments with these loads were performed to determine the regions of the high stresses. Residual and fit-up stresses were then added to the stresses evaluated due to the flight loads. A flaw in the weld was assumed to be located in the region of the highest stress and was assumed to be oriented normal to the direction of the highest stress. All of the stress values and material properties determined above were used within the NASGRO analysis to predict the rate of crack growth under expected operating conditions and thus determine the CIFS.

This paper presents the details of the methodology used to determine the CIFS for the upper stage simulator welds.