



## ▶ Finite Element Models for Electron Beam Freeform Fabrication Process

**Potential applications are in the fabrication of short-run components, and repair and refurbishment of parts in the aerospace, automotive, power generation, and other industries.**

*Lyndon B. Johnson Space Center, Houston, Texas*

Electron beam freeform fabrication (EBF<sup>3</sup>) is a member of an emerging class of direct manufacturing processes known as solid freeform fabrication (SFF); another member of the class is the laser deposition process. Successful application of the EBF<sup>3</sup> process requires precise control of a number of process parameters such as the EB power, speed, and metal feed rate in order to ensure thermal management; good fusion between the substrate and the first layer and between successive layers; minimize part distortion and residual stresses; and control the microstructure of the finished product.

This is the only effort thus far that has addressed computer simulation of the EBF<sup>3</sup> process. The models developed in this effort can assist in reducing the number of trials in the laboratory or on the shop floor while making high-quality parts. With some modifications, their use can be further extended to the simulation of laser, TIG (tungsten inert gas), and other deposition processes.

A solid mechanics-based finite element code, ABAQUS, was chosen as the primary engine in developing these models whereas a computational fluid dynamics (CFD) code, Fluent, was used in a support role. Several innovative concepts were developed, some of which are

highlighted below. These concepts were implemented in a number of new computer models either in the form of standalone programs or as user subroutines for ABAQUS and Fluent codes.

A database of thermo-physical, mechanical, fluid, and metallurgical properties of stainless steel 304 was developed. Computing models for Gaussian and raster modes of the electron beam heat input were developed. Also, new schemes were devised to account for the heat sink effect during the deposition process. These innovations, and others, lead to improved models for thermal management and prediction of transient/residual stresses and distortions.

Two approaches for the prediction of microstructure were pursued. The first was an empirical approach involving the computation of thermal gradient, solidification rate, and velocity ( $G, R, V$ ) coupled with the use of a solidification map that should be known *a priori*. The second approach relies completely on computer simulation. For this purpose a criterion for the prediction of morphology was proposed, which was combined with three alternative models for the prediction of microstructure; one based on solidification kinetics, the second on phase diagram, and the third on differ-

ential scanning calorimetry data. The last was found to be the simplest and the most versatile; it can be used with multi-component alloys and rapid solidification without any additional difficulty.

For the purpose of (limited) experimental validation, finite element models developed in this effort were applied to three different shapes made of stainless steel 304 material, designed expressly for this effort with an increasing level of complexity.

These finite element models require large computation time, especially when applied to deposits with multiple adjacent beads and layers. This problem can be overcome, to some extent, by the use of fast, multi-core computers. Also, due to their numerical nature coupled with the fact that solid mechanics-based models are being used to represent the material behavior in liquid and vapor phases as well, the models have some inherent approximations that become more pronounced when dealing with multi-bead and multi-layer deposits.

*This work was done by Umesh Chandra of Modern Computational Technologies, Inc. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24598-1*

## ▶ Autonomous Information Unit for Fine-Grain Data Access Control and Information Protection in a Net-Centric System

**Potential uses include cyber-security, smart grid, defense networks, and enterprise networks.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

As communication and networking technologies advance, networks will become highly complex and heterogeneous, interconnecting different network domains. There is a need to provide user authentication and data protection in order to further facilitate

critical mission operations, especially in the tactical and mission-critical net-centric networking environment. The Autonomous Information Unit (AIU) technology was designed to provide the fine-grain data access and user control in a net-centric system-testing environ-

ment to meet these objectives.

The AIU is a fundamental capability designed to enable fine-grain data access and user control in the cross-domain networking environments, where an AIU is composed of the mission data, metadata, and policy. An AIU pro-

vides a mechanism to establish trust among deployed AIUs based on recombining shared secrets, authentication and verify users with a username, X.509 certificate, enclave information, and classification level. AIU achieves data protection through (1) splitting data into multiple information pieces using the Shamir's secret sharing algorithm, (2) encrypting each individual information piece using military-grade AES-256 encryption, and (3) randomizing the position of the encrypted data based on the unbiased and memory efficient in-place Fisher-Yates shuffle method. Therefore, it becomes virtually impossi-

ble for attackers to compromise data since attackers need to obtain all distributed information as well as the encryption key and the random seeds to properly arrange the data. In addition, since policy can be associated with data in the AIU, different user access and data control strategies can be included.

The AIU technology can greatly enhance information assurance and security management in the bandwidth-limited and ad hoc net-centric environments. In addition, AIU technology can be applicable to general complex network domains and applications where distributed user authentication and data protection are

necessary. AIU achieves fine-grain data access and user control, reducing the security risk significantly, simplifying the complexity of various security operations, and providing the high information assurance across different network domains.

*This work was done by Edward T. Chow, Simon S. Woo, Mark James, and George K. Palouljian of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-48224.*

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## ➤ Vehicle Detection for RCTA/ANS (Autonomous Navigation System)

**This algorithm can be applied to semi-autonomous vehicles for driver assistance, and to military robots.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Using a stereo camera pair, imagery is acquired and processed through the "JPLV" stereo processing pipeline. From this stereo data, large 3D blobs are found. These blobs are then described and classified by their shape to determine which are vehicles and which are not. Prior vehicle detection algorithms are either targeted to specific domains, such as following lead cars, or are intensity-based methods that involve learning typical vehicle appearances from a large corpus of training data.

In order to detect vehicles, the JPL Vehicle Detection (JVD) algorithm goes through the following steps:

1. Take as input a left disparity image and left rectified image from JPLV stereo.

2. Project the disparity data onto a two-dimensional Cartesian map.

3. Perform some post-processing of the map built in the previous step in order to clean it up.

4. Take the processed map and find peaks. For each peak, grow it out into a map blob. These map blobs represent large, roughly vehicle-sized objects in the scene.

5. Take these map blobs and reject those that do not meet certain criteria. Build descriptors for the ones that remain. Pass these descriptors onto a classifier, which determines if the blob is a vehicle or not.

The probability of detection is the probability that if a vehicle is present in the image, is visible, and un-occluded,

then it will be detected by the JVD algorithm. In order to estimate this probability, eight sequences were ground-truthed from the RCTA (Robotics Collaborative Technology Alliances) program, totaling over 4,000 frames with 15 unique vehicles. Since these vehicles were observed at varying ranges, one is able to find the probability of detection as a function of range. At the time of this reporting, the JVD algorithm was tuned to perform best at cars seen from the front, rear, or either side, and perform poorly on vehicles seen from oblique angles.

*This work was done by Shane Brennan, Max Bajracharya, Larry H. Matthies, and Andrew B. Howard of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47569*

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## ➤ Image Mapping and Visual Attention on the Sensory Ego-Sphere

**This technology can be used to map a robot's environment and direct its attention.**

*Lyndon B. Johnson Space Center, Houston, Texas*

The Sensory Ego-Sphere (SES) is a short-term memory for a robot in the form of an egocentric, tessellated, spherical, sensory-motor map of the robot's locale. Visual attention enables fast alignment of overlapping images without warping or position optimization, since an attentional point (AP) on the

composite typically corresponds to one on each of the collocated regions in the images. Such alignment speeds analysis of the multiple images of the area.

Compositing and attention were performed two ways and compared: (1) APs were computed directly on the composite and not on the full-resolution images until

the time of retrieval; and (2) the attentional operator was applied to all incoming imagery. It was found that although the second method was slower, it produced consistent and, thereby, more useful APs.

The SES is an integral part of a control system that will enable a robot to learn new behaviors based on its previ-