1.5 High Resolution Visualization Applied to Future Heavy Airlift Concept Development and Evaluation

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Abstract. This paper explores the use of high resolution 3D visualization tools for exploring the feasibility and advantages of future military cargo airlift concepts and evaluating compatibility with existing and future payload requirements. Realistic 3D graphic representations of future airlifters are immersed in rich, supporting environments to demonstrate concepts of operations to key personnel for evaluation, feedback, and development of critical joint support. Accurate concept visualizations are reviewed by commanders, platform developers, loadmasters, soldiers, scientists, engineers, and key principal decision makers at various stages of development. The insight gained through the review of these physically and operationally realistic visualizations is essential to refining design concepts to meet competing requirements in a fiscally conservative defense finance environment. In addition, highly accurate 3D geometric models of existing and evolving large military vehicles are loaded into existing and proposed aircraft cargo bays. In this virtual aircraft test-loading environment, materiel developers, engineers, managers, and soldiers can realistically evaluate the compatibility of current and next-generation airlifters with proposed cargo.

1.0 INTRODUCTION

The application of common 3D visualization tools (Computer Aided Design, Computer Aided Engineering and Computer Graphic Animation (CAD/CAE/CGA)) along with a depth of knowledge in military vehicle transport requirements, capabilities and policies can be very fruitful in the development and evaluation of future heavy-airlift concepts.

Unbeknownst to the casual observer, the cargo carrying capacity of military heavy airlift cargo planes often defines the size limitations for military weapon platforms [1]. For example, the Stryker family of eight-wheeled vehicles, which is the backbone of the US military's Interim Force, was acquired with a C-130 transport requirement that limits the vehicle external dimensions, overall weight and center of gravity, as well as maximum axle loads. Another major acquisition program, the Future Combat System (FCS), which, until recently, was to be the primary vehicle platform for the Objective Force, initially had a C-130 requirement as well. But due to competing requirements, including ballistic protection, this requirement was dropped in favor of a less restrictive transport requirement: three FCS vehicles in a C-17 aircraft. This new requirement still imposed significant size restrictions that subsequently redefined the size and weight boundaries for the program. Yet another major acquisition program confirming this trend is the Joint Light Tactical Vehicle (JLTV), with a C-130 transport requirement that constrains the JLTV family of vehicle's size and weight.

This size-defining mechanism works in both directions. Future heavy-airlift platforms are defined and evaluated by the vehicles and cargo that they can carry. A future airlifter that is capable of delivering heavy vehicles, one at a time, or in multiples, is obviously more attractive than a less capable platform. In fact, formal government requests for information from industry regarding future heavy airlift concepts are usually defined in terms of the vehicles they must be able to transport. However, total airlift capacity is obviously not the only objective of a heavy airlift concept [2].

Future heavy airlift concepts are evaluated against a variety of performance factors beyond dimensional, structural, and weight carrying capacities. These additional factors include range and speed of delivery, fuel efficiency, takeoff and landing capabilities (runway requirements: length, condition, elevation), self-protection capabilities, and cargo handling capabilities (ease and speed of loading, securing, unloading) among others [3]. The effectiveness of a future heavy airlifter platform development program depends upon clear communication of the capabilities inherent in a design, the ultimate impact of these capabilities, as well as critical feedback from a wide audience of critical stakeholders. Generally speaking, these stakeholders include buyers, builders, users and the general public. More specifically, these stakeholders include congress and the media, senior level military commanders and civil service leadership, program managers and engineering staff, cargo handling personnel (including Air Force Loadmasters), and soldiers among others. Each of these stakeholders has valuable input and feedback that, given the opportunity, can be facilitated, solicited and obtained via a visually accurate concept demonstration visualization.

2.0 FUTURE HEAVY AIRLIFT CONCEPT VISUALIZATIONS

Future Heavy Airlift Concept Visualizations are technically oriented, highly-descriptive, and concise videos based on conceptual CAD geometry, supporting 3D graphic objects and environments, thorough knowledge of the concepts of operations, and realistic limitations. MECHSIM Defense Transportation Technologies, Incorporated (MECHSIM) has provided technically oriented concept demonstration visualizations to the military heavy lift transportation community since 2000. Concept demonstrations have been provided to US Army Defense Ammunition Logistics Activity (AMMOLOG) at Picatinny Arsenal, The Boeing Company Advanced Mobility Interface Systems group, The Boeing Company Phantom Works, and The US Army Aviation Applied Technology Directorate (AATD) at Fort Eustis, among others.

Effective concept demonstrations clearly and accurately convey the need for a new heavy airlift concept, the essence of the proposed concept, the technical features and capabilities, the concepts of operation, as well as the ultimate impact upon the target industries. Figure 1 shows still images from the Joint Heavy Lift (JHL) High Efficiency Tilt Rotor (HETR) concept visualization produced for AATD in 2010. These highlights illustrate a sampling of 1) the need for a new heavy airlifter to overcome infrastructure limitations, 2) the layout and capacity of the HETR concept, 3) the technologies being developed in support of JHL HETR, 4) the payload/range capabilities of JHL HETR, 5) the flexibility of the HETR design in takeoff and landing modes , and 6) the range of operations that JHL HETR can support including military operations, homeland security and humanitarian relief [4].

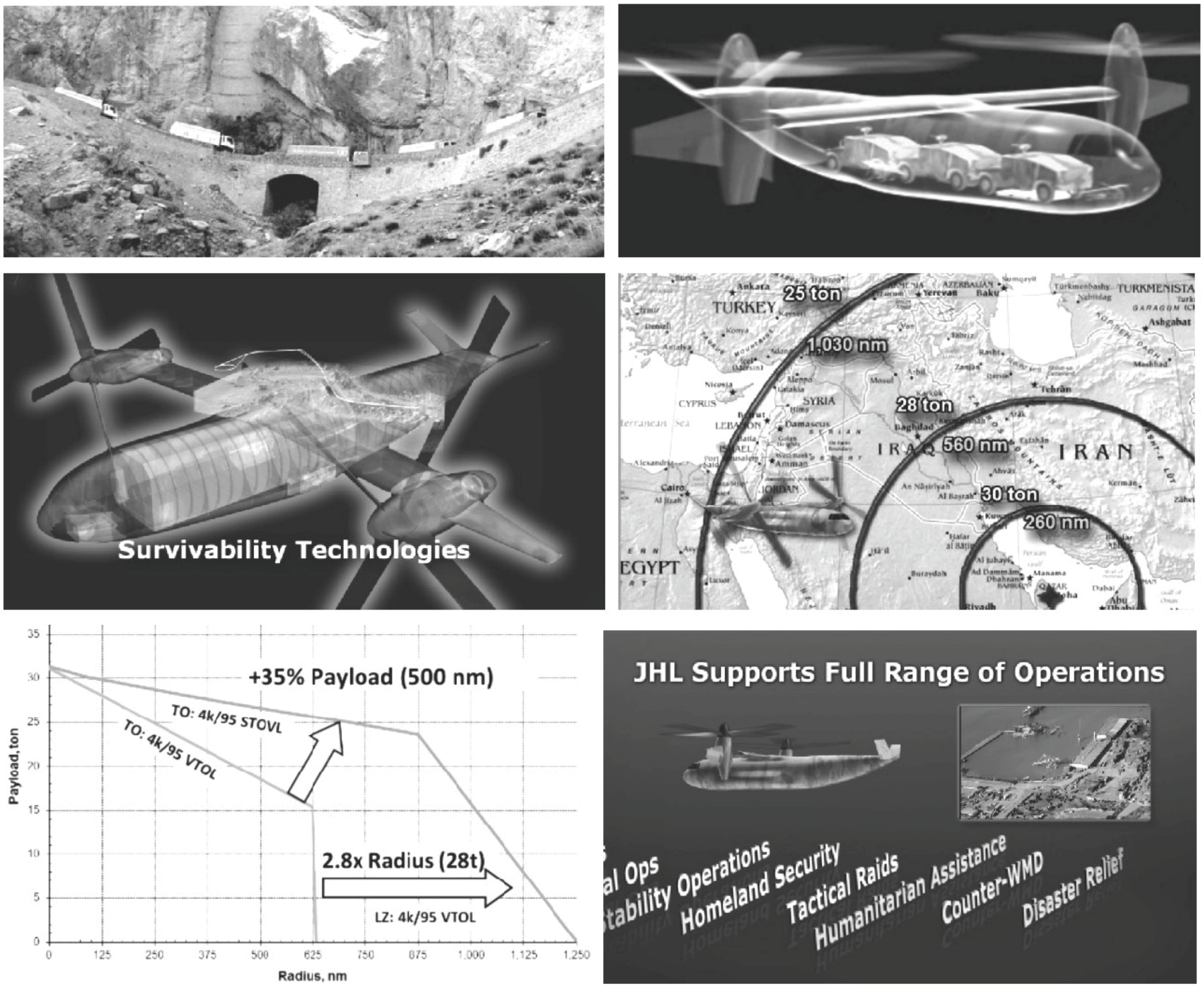

Figure 1. Joint Heavy Lift High Efficiency Tilt Rotor concept visualization still Images

2.1 Future Heavy Airlift Concept Visualizations: Process

Visualization development begins with interviews of the proponents and developers, along with background research to obtain a full understating of the concept. Data collection ensues, including CAD model data and supporting media: brochures, presentations, media reports, live photographs and video clips. These are reviewed for usefulness in conveying the intended message. Next, a descriptive storyboard is formulated in close coordination with the client. Depending upon budgetary and schedule constraints, the concept demonstration may incorporate a narrative script with voiceover, sound effects and background music. The storyboard continues the collaborative development and review process until all parties are satisfied that it conveys the intended message in a concise and easy to understand manner.

The geometry for the concept is obtained from the developers and converted into the animation software format and optimized for visual impact and rendering efficiency. This includes deletion of unnecessary features and addition of texture maps, colors and lighting effects. Supporting objects, including other vehicles, material handling equipment, cargo representations are obtained or created and prepared for animation and rendering. Supporting environments are obtained or generated to illustrate concepts of operation in appropriate realistic scenarios. Once all geometry import and clean up is complete, it is adjusted for consistency in level of detail and artistic style and reviewed in detail with the client. Upon approval, computer generated graphic media production ensues as quickly as possible.

When the storyboard and script are finalized and substantial animation media is complete, composite video editing begins and draft video segments are produced and reviewed. This iterative process continues until a full draft concept demonstration video is produced. This draft video is reviewed at length with the client as well as other critical stake-holders. Upon successful modification, a complete concept demonstration video is delivered in multiple media formats, including standard definition, high definition and web-streaming video. In addition, if requested, the final video and associated clips are edited down to smaller segments targeted for specific applications including trade-show looping videos and videos targeting certain groups.

2.2 Future Heavy Airlift Concept Visualizations: Tools

While none of these activities alone comprise basic research, the balanced and skillful application of the collective toolset results in high impact cutting edge visualizations. The required skill-set includes: story-telling/crafting, communication, teamwork and problem solving, budget, schedule and resource allocation, familiarity with the industry, its language and challenges, animation and video editing, audio composition and voice-over talent, and attention to details. The ability to balance competing objectives, including client wishes, budget, schedule, employee resources and skills, is paramount. Visualization development also requires leading edge computer hardware and software, including multiple processors, large processing and graphics memory, multiple monitors, and substantial hard-drive capacity and speed for rendering storage. A network of high-powered PCs can expedite the iterative rendering process. Software requirements include CAD geometry translation software, cutting edge commercial computer-graphic-animation software, video editing software and audio composition software.

2.3 Future Heavy Airlift Concept Visualizations: Application

The most obvious use of future heavy airlift concept visualization is in marketing venues. Quality visualization persuasively conveys the need for and utility of a new concept. However, a much less common, often overlooked and undervalued, application is in the development and evaluation of the new concept. New concepts typically are born out of discussions among end-users, technology developers, leadership and visionaries. Discussions evolve into sketches and bullet points. White papers are generated, and some preliminary quantitative analyses are often conducted. These are the seeds of a new concept. If a concept is believed to hold substantial merit, an organization may begin to apply engineering resources to its development. It is at this early, critical stage, that technical visualization tools can be leveraged to dramatically enhance the concept development process.

This innovative approach was effectively used by the US Army Armament Research, Development and Engineering Center (ARDEC) Program Manager for the Joint Modular Intermodal Distribution System (JMIDS), Mr. Doug Chesnulovitch, to expedite development and reduce costs. As shown in Fig. 2, JMIDS was a Joint Concept Technology Demonstration program, consisting of three components that improve the efficiency of heavy cargo distribution operations: 1) JMIP platforms (Joint Modular Intermodal Platform) that are PLS (Palletized Loading System) load handling capable, aircraft direct-load compatible, and

ISO container compatible, 2) Joint Modular Intermodal containers (JMIC) that are multimode compatible, and 3) electronic tracking devices. ARDEC's Ammunition Logistics Activity (AMMOLOG) worked with multiple developers, the user community, and joint leadership for a period of several years to develop a variety of concepts. These concepts, ranging from special pallets and flatracks to a variety of containers, eventually converged to the JMIDS system [5].

Figure 2. Joint Modular Intermodal Distribution System concept demonstration.

AMMOLOG utilized technical concept visualizations throughout the development process to capture and illustrate the features, capabilities and operations of each concept without building expensive physical prototypes. These visualizations were used in working group meetings and leadership reviews to rapidly and accurately convey concept information and solicit quality feedback. Upon viewing the visualizations, the audience members were able to immediately collaborate on the design and contribute valuable feedback from their unique and diverse perspectives. This saved immeasurable time and resources normally devoted to development, building and testing of hardware prototypes. Thus the virtual reality visualizations stimulate creative thinking, problem solving and brainstorming among groups. This same approach has been applied to several alternative heavy lift concepts from The Boeing Company as shown in Fig. 3.

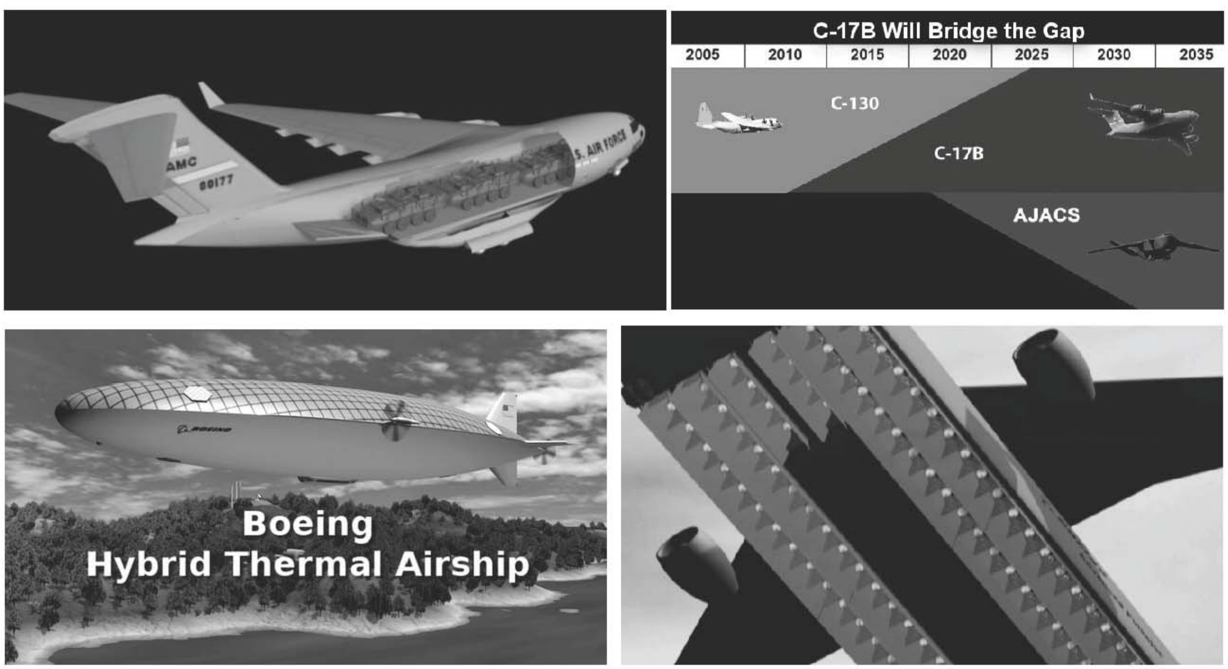

Figure 3. Heavy lift concept visualization images created for Boeing (C-17B density loading, C-17B bridges capability gap, ultra heavy lift Hybrid Thermal Airship, Pulse Ejector Thrust Augmenter Pulse-Jet for VTOL).

3.0 FUTURE HEAVY AIRLIFT CAPACITY ANALYSIS

Future heavy airlift concepts can also be evaluated in virtual space for cargo carrying capacity, and compatibility with existing and planned cargo types. This can be done on a gross level with basic overall dimensional comparisons, and then with increasing fidelity as the design matures and engineering data becomes available. Compatibility assessments between large payloads and heavy airlifters can be conducted in both directions: A future airlift asset can be evaluated against existing heavy cargos, and a new weapon platform or vehicle, can be evaluated for compatibility with existing heavy airlift resources.

Figure 4, below, shows a virtual C-130 test loading aircraft. This model has the basic exterior geometry of a C-130, including props and landing gear, for visual effect. But more importantly, this model has detailed interior cargo bay geometry, and floor, ramp and cargo handling features that are validated for accuracy. The interior surfaces were developed from laser-radar scanning with a quarter-inch tolerance. The floor, including rollers, rails and tiedown points is based on published Air Force data, and has also been validated for accuracy. This model was used extensively in the development of the US Army Stryker Light Armored Vehicle.

Figure 4. Virtual C-130 test loading aircraft.

The Stryker program is a family of vehicles that require C-130 transport. This requirement challenged the vehicle developers in several areas. The vehicle had to meet certain C-130 weight criteria while also being operational upon delivery. In addition, the aircraft has certain structural limitations in the floor and ramp that limit axle loads both statically and dynamically during the loading process. Finally, the Air Force requires a crawl space either over or beside the vehicle for the loadmaster to move from front to rear of the aircraft during flight. MECHSIM modeled the physics of the suspension system together with the vehicle CAD geometry and conducted virtual aircraft test loadings to measure clearances (or interference), axle loads, and available crawl space. These analyses were conducted iteratively with incremental adjustments in suspension settings and design modifications until the vehicle was successfully loaded and secured in the virtual environment. This process expedited the progress towards the ultimate vehicle designs and loading procedures, and substantially reduced the cost and delays of physical testing that would have been required otherwise. Without this type of tool, the Stryker family of vehicles may have never received C-130 flight certification. Figure 5 shows a comparison of crawl space clearance in the model and in reality.

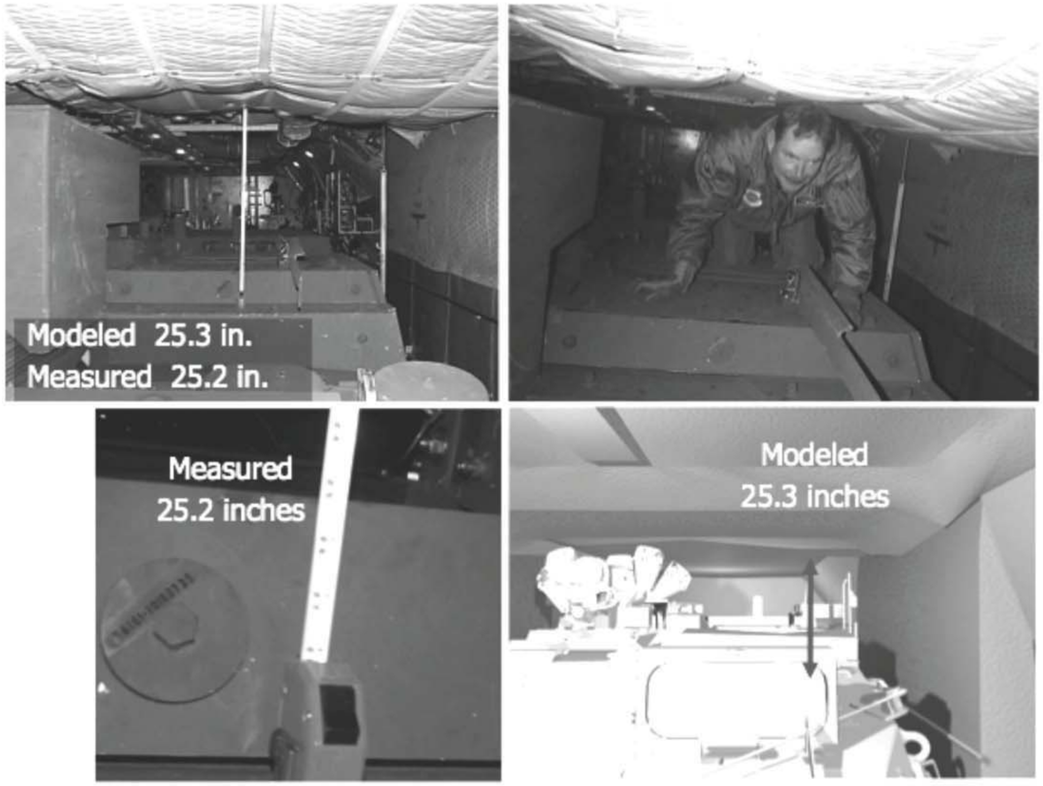

Figure 5. Comparison of Stryker/C-130 crawl space clearance in the model and in reality (crawl space between vehicle hatch and C-130 wingbox, crawl space live test, measured crawl space overhead clearance, and modeled crawl space clearance).

In addition to predicting clearances and axle loads, virtual aircraft test loadings are useful for developing load plans, including vehicle placement and chain tiedown patterns, for existing and developmental vehicles and aircraft concepts. This type of analysis was conducted in great detail for a large number of FCS manned ground vehicle C-17 load combinations from 2008-2009. Although the FCS program was cancelled, the value of insight gained and the expedience of the analysis and feedback is fully established.

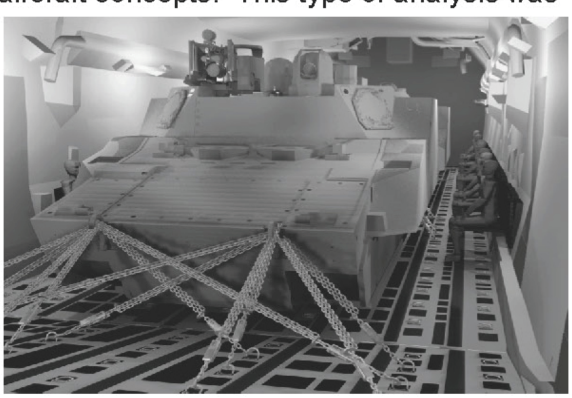

Figure 6. Image from detailed virtual test loading of FCS in C-17 aircraft.

Thus, similar tools and data for heavy lift concept visualization can also be applied to virtual aircraft test loadings for evaluating the compatibility of large cargo items (military vehicles in particular) with existing and future airlift platforms. The accuracy and certainty of the results depends upon, and grows with, the availability, quality and fidelity of relevant engineering data. This allows heavy lift concept developers as well as vehicle/ cargo developers to make informed decisions and adjustments to the design of a platform without the need and cost of physical prototyping and testing.

4.0 CONCLUSION

High resolution 3D visualizations have been used effectively for both marketing purposes as well as concept development facilitation for heavy airlift concepts. Detailed, accurate 3D models of heavy lift aircraft and large military vehicles are also useful for compatibility analysis and guiding the design process. In summary, the application of common computer aided design and engineering visualization tools along with knowledge, skill and patience can be very fruitful in the development and evaluation of future heavy-airlift concepts and the associated large military vehicle payloads.

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