



KRATOS

FINITE ELEMENT ANALYSIS SIMULATION & DESIGN OPTIMIZATION FOR DEFENSE TRAINING SYSTEMS

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NDIA Physics-Based Modeling In Design & Development for U.S. Defense Conference.

5-8 November 2012, Denver, CO

Presentation Outline

- **Introduction**
- **Kratos Training Solutions Overview**
- **Kratos Training Solutions Capabilities**
- **Case Study**
 - **Tracked Combat Vehicle Hands-On-Trainer System Design & Development:**
 - **Physics-Based Modeling Virtual Prototype**
 - **FEA & Structural Mechanics Simulation**
 - **Trainer Structural Design Optimization**
- **Concluding Remarks**

Kratos Defense and Security Solutions Profile

Highly agile and responsive to changing needs and priorities

- Growing with alignment to meet DoD priorities: 41% growth rate since 2003 (one of the fastest growing companies in our industry)
- Resources to deliver a single solution or end-to-end support for strategic programs
- FY2012 Revenue of approx. \$1B
- Approx. 4,400 employees

Broad solution portfolio with diversified expertise



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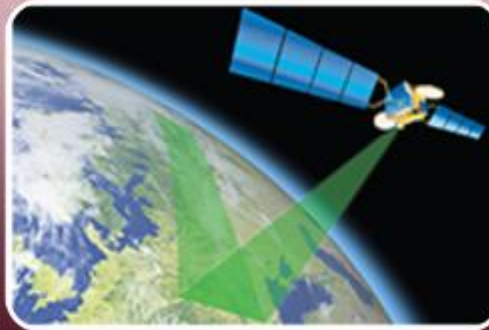


Kratos International Presence With Strong Local Relationships

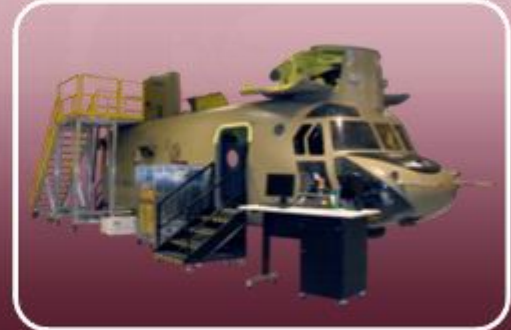


58 locations worldwide with headquarters in San Diego, CA

Kratos Technology and Training Solutions



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CyberSecurity

- Cyber Security and Information Assurance
- Enterprise Information Management
- Network Operations and Management

Communications

- Command and Control
- Signal Processing & Data Communications
- Communications Information Assurance
- SATCOM Network Operations
- MILSATCOM Products

Training

- Simulation & Training Systems
- Virtual Systems
- Courseware Development
- Training Analysis
- Sustainment and Logistic Support
- Workforce Planning
- Education Programs

Kratos Training Solutions Overview Services

Front End Analysis

Solution Design

Solution Development

Deployment & Support

Services

- Front End Analysis, Finite Element Analysis (FEA) and Instructional Systems Design (ISD)
- Courseware Design/Development
- Education Programs
- Learning Management
- Sustainment and Logistics Support



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17 Years of Experience in the Simulation and Training Market

Kratos Training Solutions Overview

Instructional System Design & Virtual Products

- Front End Engineering Analysis
- Interactive Multimedia Instruction
- Web-Based, SCORM Conformant IMI
- Instructor-Led Training Products
- Desk-Top Training Systems
- Micro-Sims
- Electronic Classrooms



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Delivered: Over 2400 Courseware Hours

Kratos Training Solutions Overview

Products

Professional Engineering
Services

Upgrade Existing
Training Systems

Full Training System
Design & Development

Products

- Full-Scale Operational Training Systems
- Full-Scale Maintenance Training Systems
- Part-Task Trainers
- Computer Based / Desktop Training Systems
- Virtual Training Systems
- Mobile Application Training



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Kratos Training Solutions Overview

Virtual Training Environment

- Operational Checks and Fault Isolation Task Support
- Fully Capable of re-configurable to multiple platforms and systems
- Fully interactive replication of cockpit displays and controls
- Stand-alone IOS with self-run capability
- IETMs displayed on integral computer



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Virtual Environment Aviation Maintenance Training

Kratos Training Solutions Overview

Platforms & Systems

Platforms & Systems

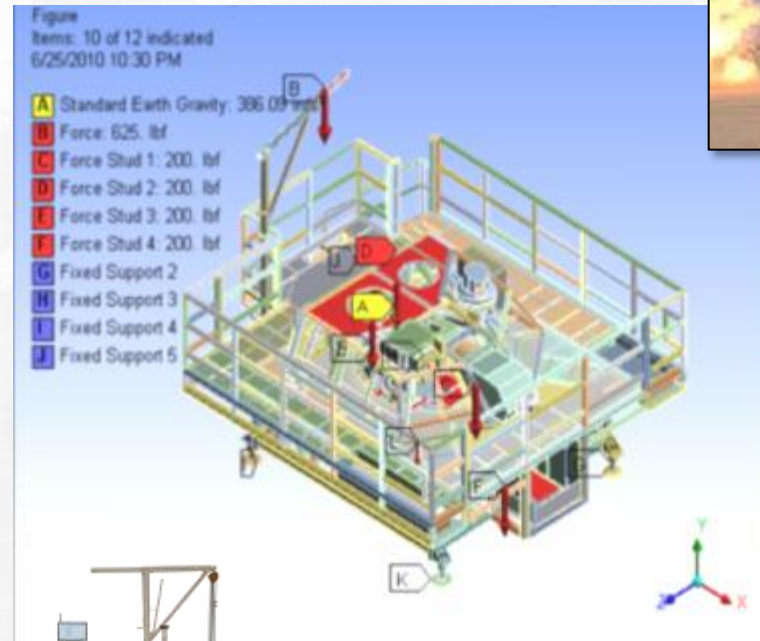
- Aircraft (Fixed and Rotary Wing)
- Ground Combat Vehicles
- Unmanned Aerial Vehicles (UAV)
- C4ISR, Cyber and Electronic Warfare Systems



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Kratos Training Solutions Capabilities Requirements Analysis

- **Requirements Analysis & System Design Capabilities**
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- New Facility



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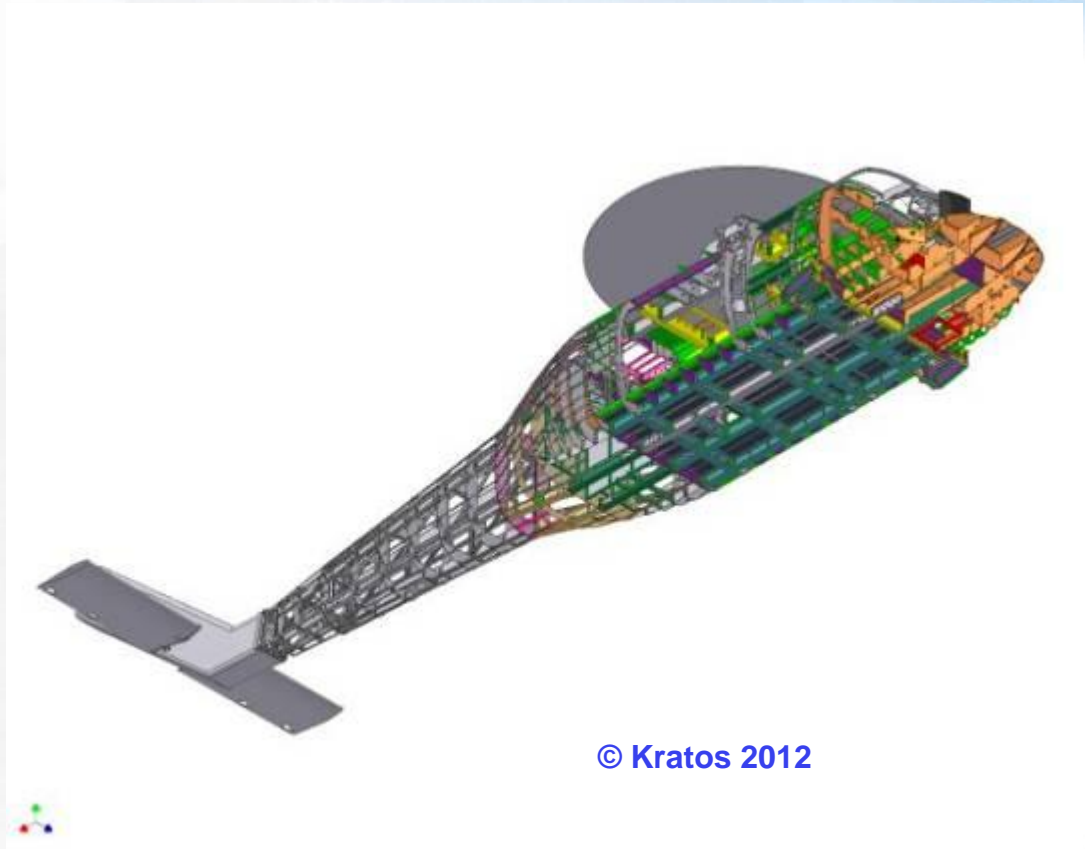
**Combat Tank Hands-On-Trainer
(HOT) for Turret Maintenance**

FEA & Engineering Analysis to Optimize Structural Integrity for Student Safety

Kratos Training Solutions Capabilities

Large Airframe System Design

- **Requirements Analysis & System Design Capabilities**
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- New Facility



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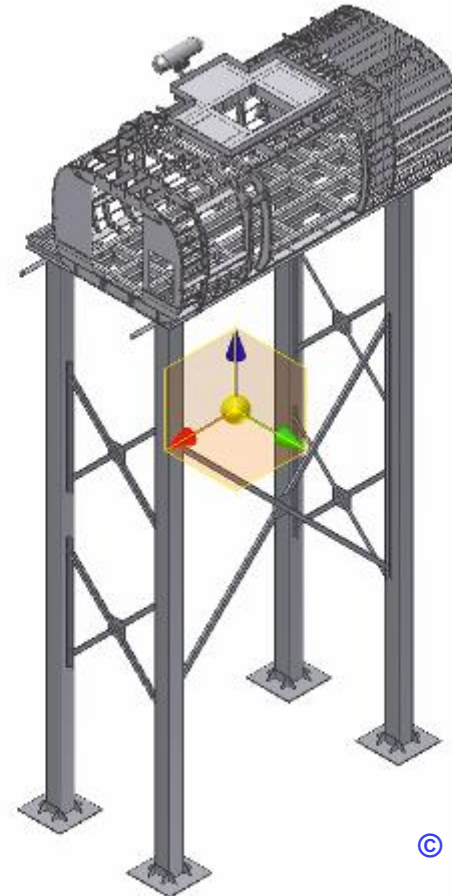
**Aircraft-Rotorcraft Remove & Replace Trainer
Structural CAD 3D Model**

Replicating Large Airframe Structures Through the Use of CAD 3D Modeling

Kratos Training Solutions Capabilities

Complex Structural System Design

- **Requirements Analysis & System Design Capabilities**
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- New Facility



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Replicating Aircraft Static Hoist Rescue Structural Design Through 3D Modeling

Kratos Training Solutions Capabilities

Development, Manufacturing & Electrical Assembly

- Requirements Analysis / System Design Capabilities
- **Development, Manufacturing and Assembly Capabilities**
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- New Facility



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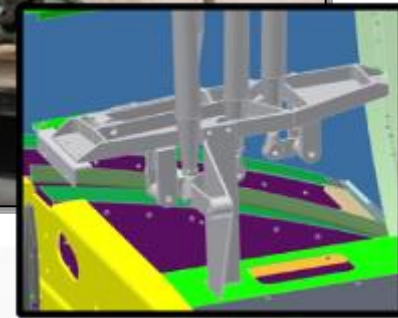
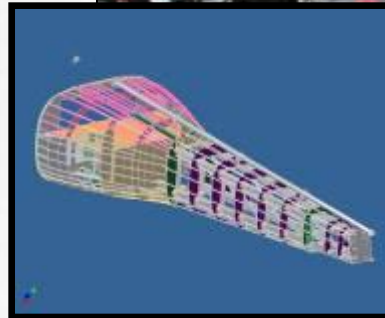
Cargo helicopter harness assembly under construction in accordance with the design Technical Data Package (TDP)

High Quality, Repeatable Cables and Harnesses Manufacturing

Kratos Training Solutions Capabilities

Development, Manufacturing & Mechanical Assembly

- Requirements Analysis / System Design Capabilities
- **Development, Manufacturing and Assembly Capabilities**
 - Electrical
 - **Mechanical**
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- New Facility



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Utility helicopter fuselage & linkages mock-up fabricated from measurements taken from actual airframes

Replicating Complex Tactical Military Structures Through CAD

Kratos Training Solutions Capabilities

Software Development

- Requirements Analysis / System Design Capabilities
- **Development, Manufacturing, & Assembly Capabilities**
 - Electrical
 - Mechanical
 - **Software**
- Deployment
- Post Deployment Support
- Technical Manual Development
- New Facility



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Demonstrating the cargo helicopter avionics functions through software modeling

Software Engineering Simulation for Modeling Complex Avionics Systems

Kratos Training Solutions Capabilities

Deployment

- Requirements Analysis / System Design Capabilities
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- **Deployment**
- Post Deployment Support
- Technical Manual Development
- New Facility



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A virtual collective vehicle simulator being loaded for highway transportation

Shipping to and Installing at Military Training Sites

Kratos Training Solutions Capabilities

Post Deployment Support

- Requirements Analysis / System Design Capabilities
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- **Post Deployment Support**
- Technical Manual Development
- New Facility



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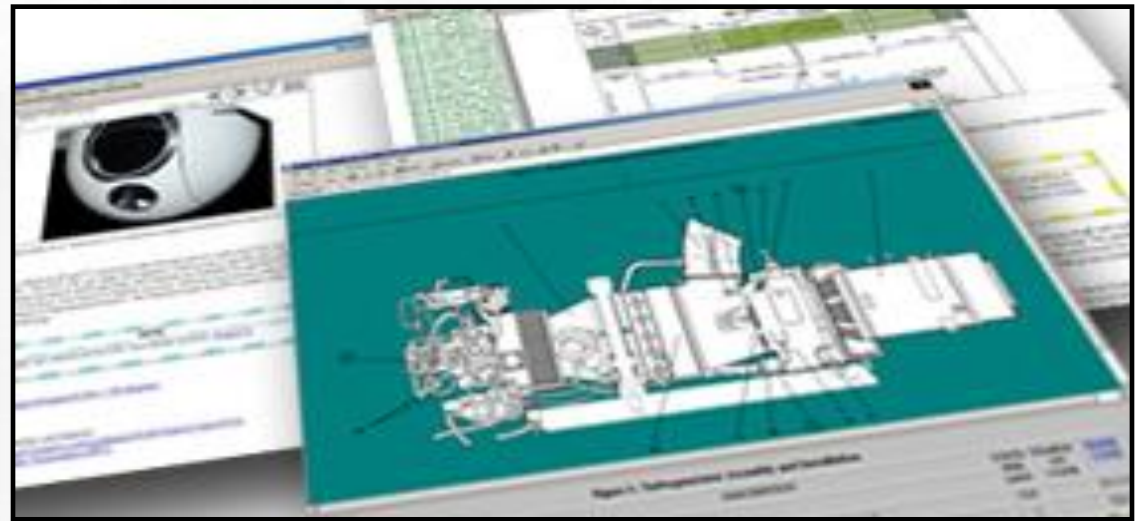
Utility helicopter avionics trainer under going life cycle maintenance checks after installation

Providing Warranty and On Call Technical Support Services

Kratos Training Solutions Capabilities

Technical Manual Development

- Requirements Analysis / System Design Capabilities
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- **Technical Manual Development**
- New Facility



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Delivered: Over 75 Technical Operation and Maintenance Manuals

Kratos Training Solutions Capabilities

New Facility

- Requirements Analysis / System Design Capabilities
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- **New Facility**



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Infrastructure Supports Synchronized, Simultaneous Manufacture Activities

Kratos Training Solutions Capabilities

New Facility Location

- Requirements Analysis / System Design Capabilities
- Development, Manufacturing, & Assembly Capabilities
 - Electrical
 - Mechanical
 - Software
- Deployment
- Post Deployment Support
- Technical Manual Development
- **New Facility**

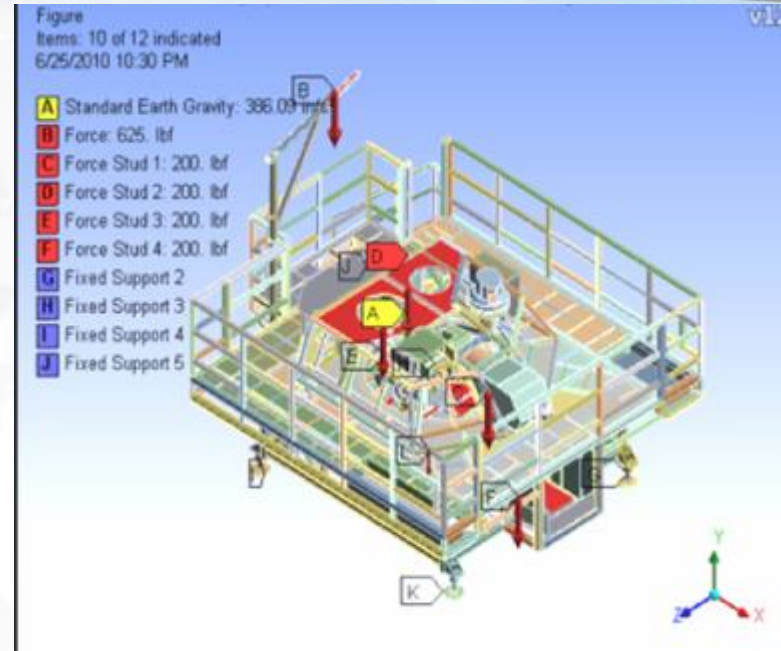
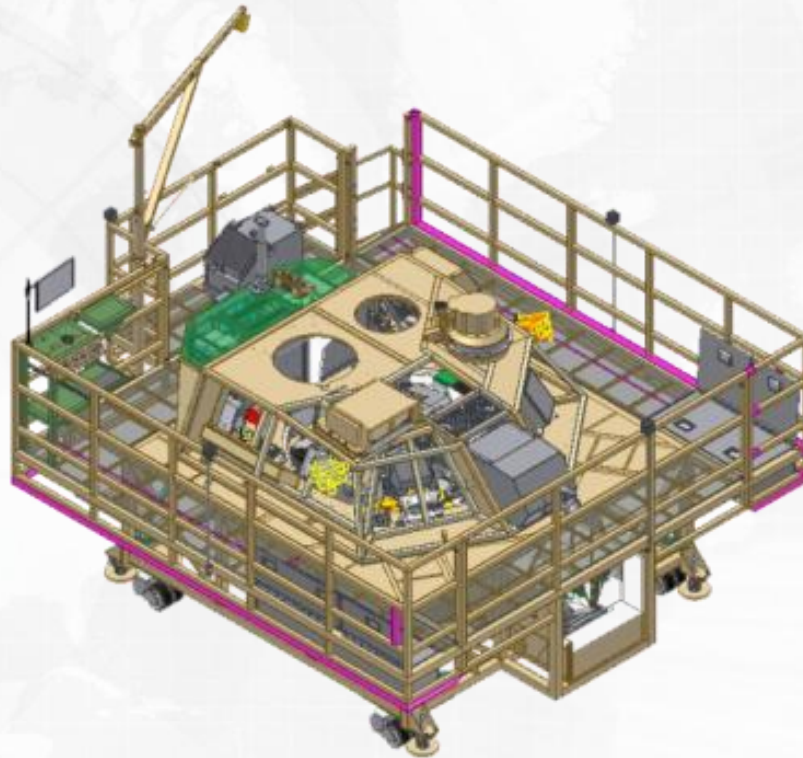


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Over 100,000 square feet of office space, production area and fabrication shop located at International Corporate Park east of Orlando International Airport

Fully Integrated Facility with 27 ft Clearance Production Area & Fabrication Shop

Case Study: Tracked Combat Vehicle Hands-On-Trainer System Design & Development



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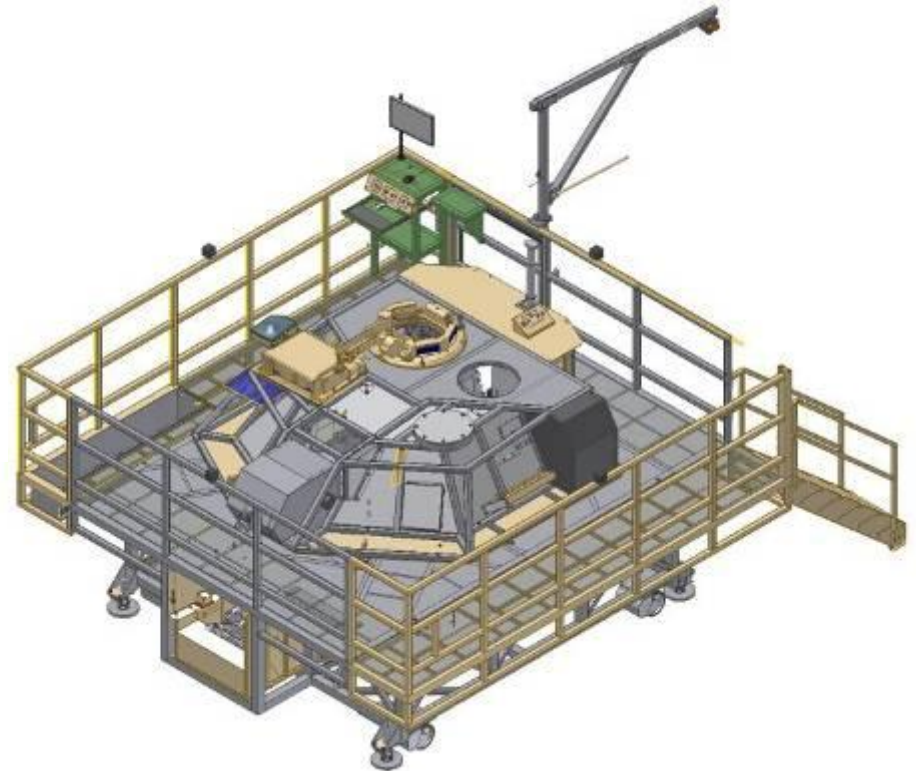
Tracked Combat Vehicle Hands-On-Trainer (HOT) Turret
Maintenance System Design & Development

FEA and Structural Mechanics Simulation for System Design Optimization

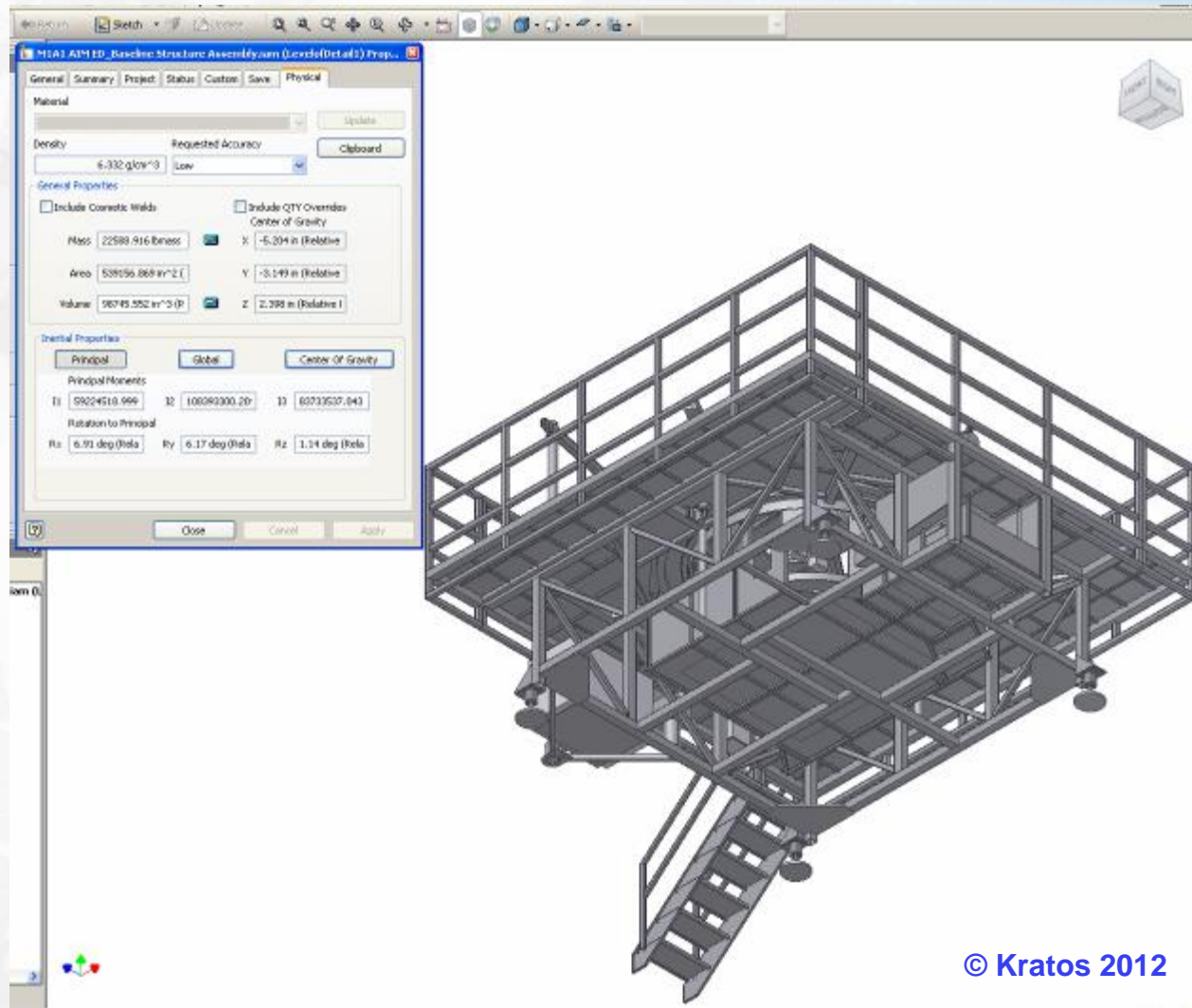
Physics-Based 3D Model Virtual Prototype Design



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3D Model Virtual Prototype Initial Physical Properties



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Benefits of FEA & Engineering Simulation in the Design Process

- **Correction of Failure**
- **Robustness of Design**
- **Improving of Safety Factor**
- **Validation of a Virtual Prototype Design**
- **Reducing Product Design and Development Cost and Product Design and Development Time**

ANSYS Structural Mechanics & FEA Simulation Technology Key Advantages

- Unequaled depth in technology
- Unparalleled breadth in physics
- Ability to perform comprehensive multi-physics
- Innovative, and higher quality, with more reliable products
- Dramatic time-to-market improvement
- Increased engineering productivity

ANSYS Structural Mechanics & FEA Simulation Technology Advantages (Continued)

- **Minimizes development and liability cost**
- **Excellent technical and customer support experience**
- **A worldwide engineering simulation organization**
- **ANSYS can provide the best integrated simulation driven product development environment available in the market today**

Engineering Simulation Best Practices in the Design Process

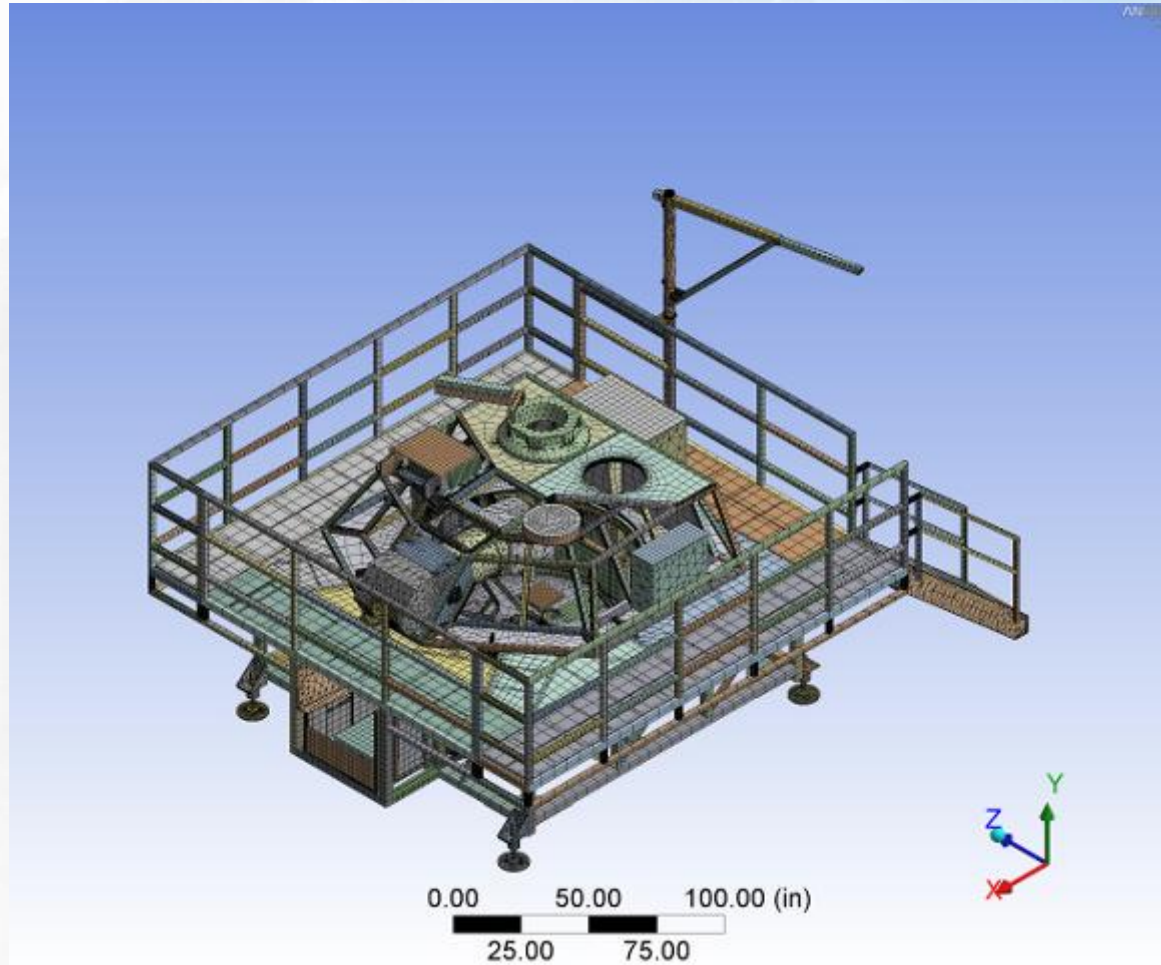
- **Creation of detailed 3D CAD model virtual prototype**
- **Ensure high fidelity mass and inertial properties**
- **Assign correct materials and physical properties for each component at the beginning of design process**
- **Have fully constrained the 3D CAD assembly and component models with mating surfaces in contact**

Engineering Simulation Best Practices in the Design Process (Continued)

- **Clean up the model geometry assembly from gaps & interferences between components**
- **Suppress small holes & threaded surfaces with little effect on the overall design to reduce solving time**
- **Eliminate small fillet radii to avoid stress riser effect**
- **Ground each adjacent model to avoid the floating components movements during FEA mesh solving**

FEA Simulation Mesh Results

- Total Nodes = 1,771,022
- Total Elements = 403,996
- Total Degrees of Freedom (DOF) = 10,626,132

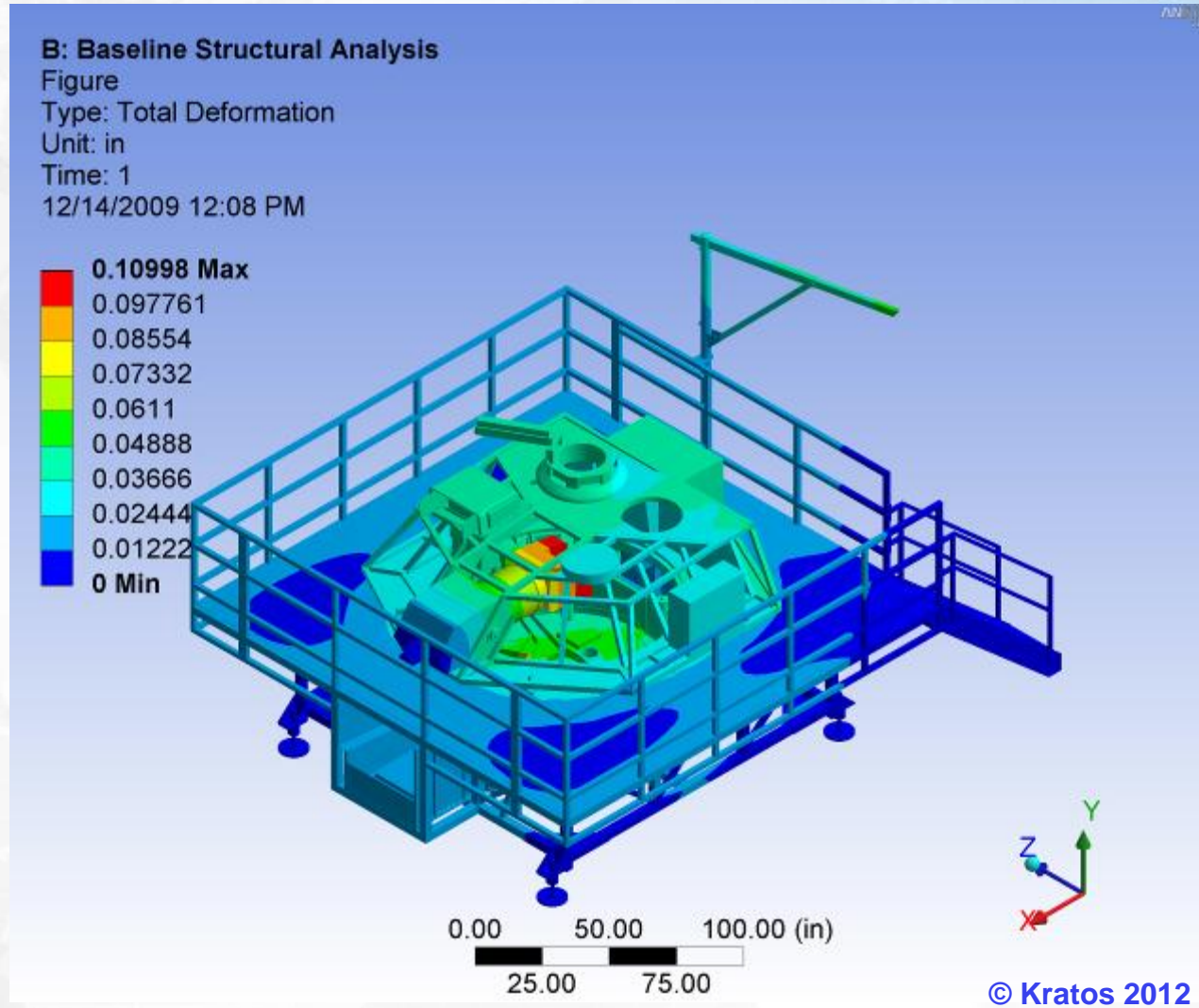


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Static Structural Analysis Simulation Assumptions

- **Maximum Class Size = 17 students**
- **Maximum Amount of Load Applied = 3,550 lb via 18 Separate Forces:**
 - **17 Students of 200 lb each**
 - **1 IOS Load of 150 lb**
- **Total Number of Supports = 5**
 - **4 Jack Screw Pads**
 - **1 Rear Stairs**

Static Structural Analysis Simulation Initial Results



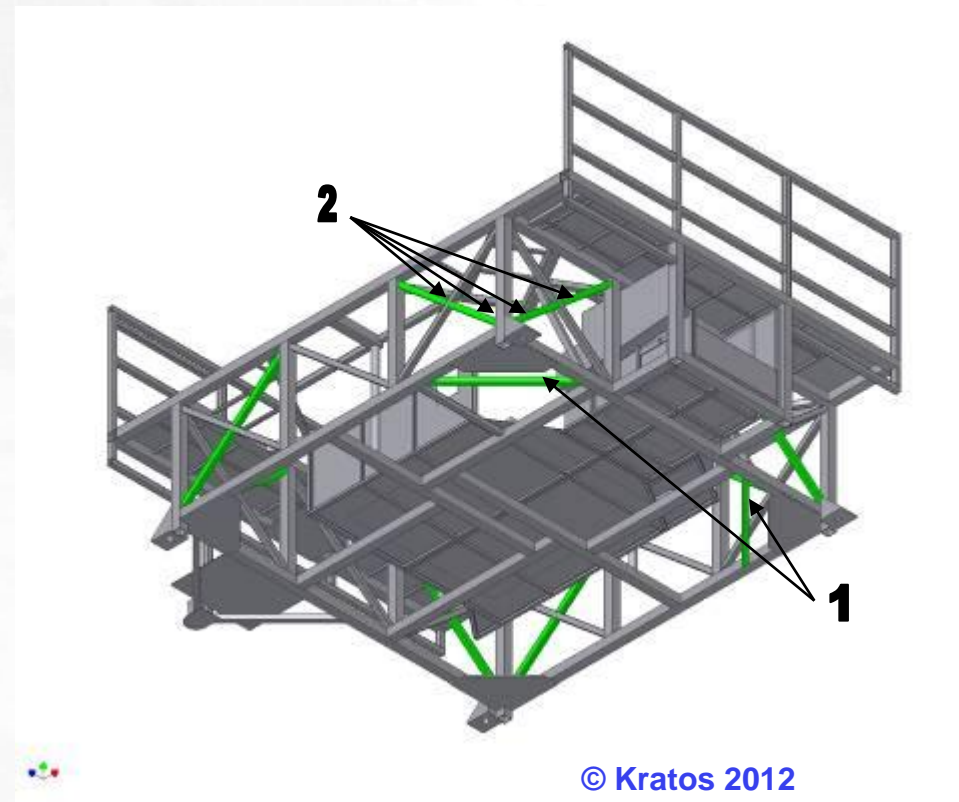
Static Structural Analysis Simulation Initial Results

(Continued)

- **The Minimum Safety Factor (SF) was below 1.0 at:**
 - **Turret Stand (Hull) Assembly**
 - **Cross Beam Side Tubes Supports**
 - **Bottom 45 Degree Tubes Supports**
 - **Turret Assembly**
 - **Base Forward Support Posts**
- **Required to reinforce the above structural components to improve the Minimum SF**

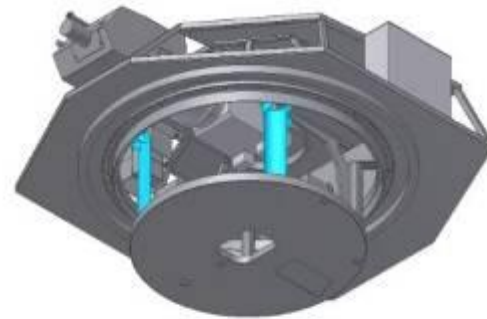
Trainer Hull Structure Design Optimization

1. Added 2 horizontal steel structural tubes on bottom frame front corners
2. Added 16 lateral steel cross beams: 8 upper and 8 lower on each vertical post corner

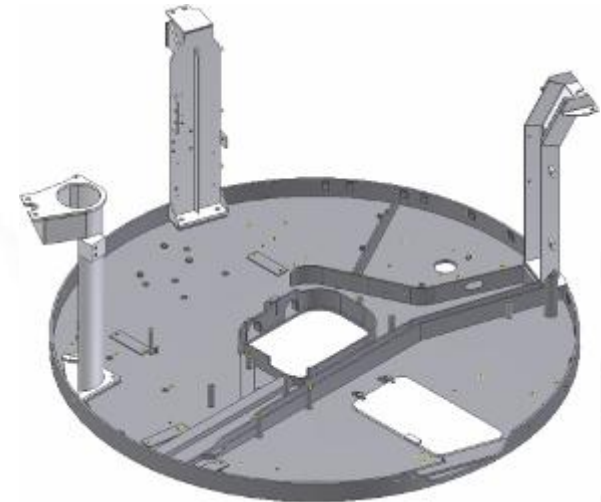


Trainer Turret Structure Design Optimization

- **Turret base forward support posts: Changed material from Aluminum to Steel**
- **Turret basket support assembly: Replaced with a tactical base basket component material**



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Trainer Reinforced Structure Physical Properties

- **Structural Reinforcement Design Optimization Total Weight Added:**
 - **Trainer Platform Assembly = 261.54 lb**
 - **Hull Assembly = 193.27 lb**
 - **Turret Assembly = 68.27 lb**

Trainer Reinforced Structure Physical Properties (Continued)

Physical

Material:

Density:

General Properties

Include Cosmetic Welds Include QTY Override

Center of Gravity

Mass: X:

Area: Y:

Volume: Z:

Inertial Properties

Principal Moments

I1	<input type="text" value="60121302.490"/>	I2	<input type="text" value="109871129.00"/>	I3	<input type="text" value="84676294.753"/>
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Rotation to Principal

Rx	<input type="text" value="6.84 deg (Rais)"/>	Ry	<input type="text" value="6.07 deg (Rais)"/>	Rz	<input type="text" value="1.26 deg (Rais)"/>
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Reinforced Structure Static Structural Analysis Simulation Results

A: Baseline Reinforced Structural Analysis Max Load

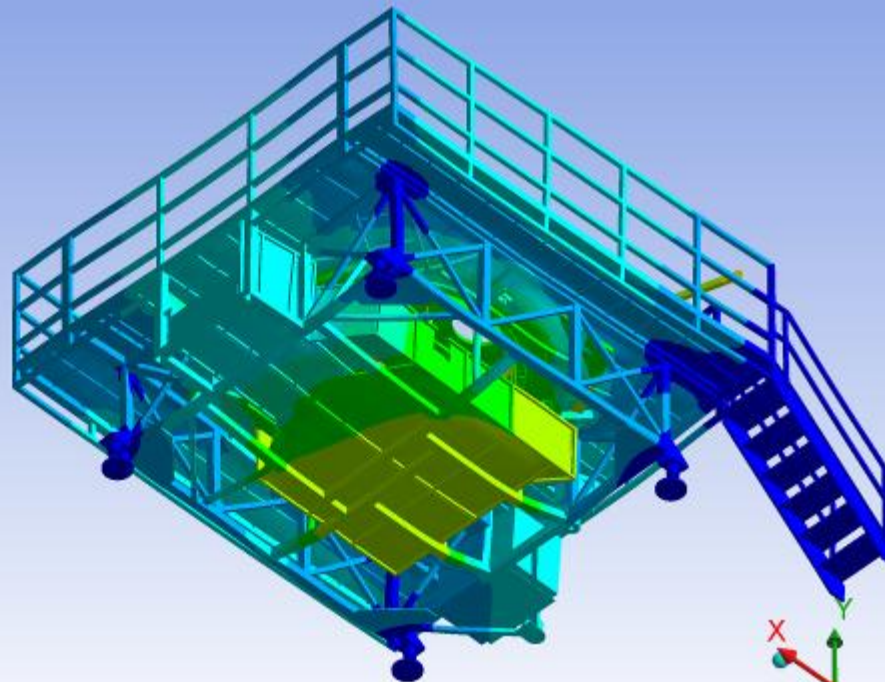
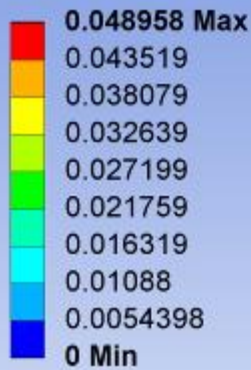
Figure 2

Type: Total Deformation

Unit: in

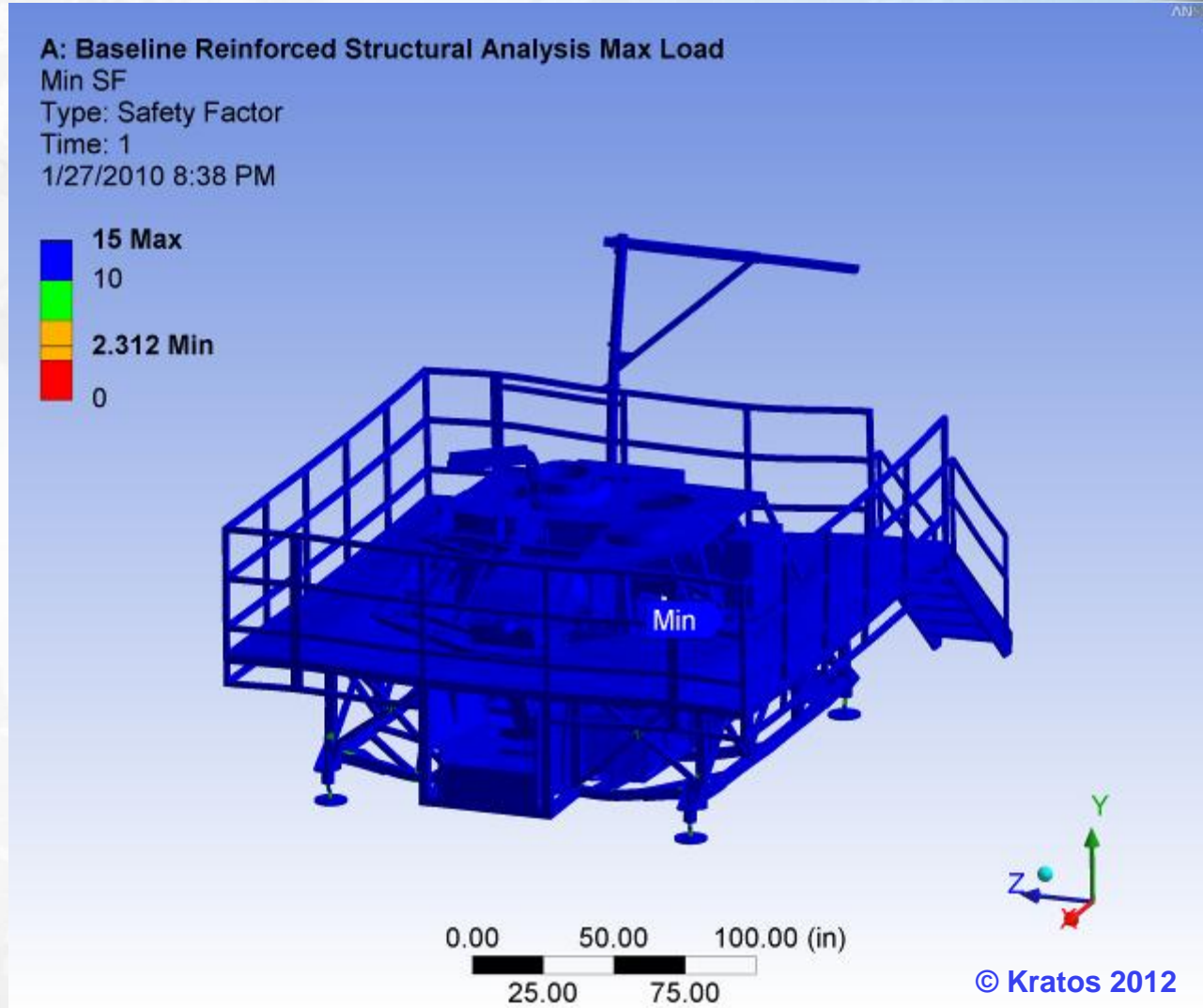
Time: 1

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Reinforced Structure Static Structural Analysis Simulation Results (Continued)



Reinforced Structure Static Structural Analysis Simulation Final Results

- **Concluded all critical area Safety Factors (SF) above 5.0 with no concerns**
- **Minimum SF of 2.312 at non-critical component on Turret upper structure**
- **Physically built & tested trainer systems matched the virtual prototype simulation predictions and no changes were required to the final design**

Tracked Combat Vehicle Maintenance Trainer System Final Development



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Tracked Combat Vehicle Maintenance Trainer System Final Development



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Concluding Remarks

- **Optimized & validated the product design based in 3D virtual prototype prior to cutting any metal**
- **ANSYS Structural Mechanics & FEA Simulation helped to correct the initial design concept without having to build a costly physical prototype**
- **FEA Simulation & Design Optimization reduced product design & development cost allowing shortened time to market**

Concluding Remarks (Continued)

- **The tracked combat maintenance training systems were developed on budget and also ready to be deployed within the program constraints**
- **Reuse of design constrains applied to other virtual prototypes saves time and money**
- **Simulation helped to improve the training system design integrity and overall safety**

Concluding Remarks (Continued)

- The good results in getting the product design right the first time helped to validate the effectiveness of FEA simulation in our design optimization process
- Received industry recognition

Military Training Technology's



2011 & 2012 Kratos Training Solutions Major Recognitions