Today’s Agenda

• Introductions
  – TEN TECH LLC Services & Solutions
  – MSC Software, MSC One & MSC Apex

• CubeSat Validation with MSC Apex
  – Mechanical Specifications
  – Finite Element Modeling & Analysis

• Closing Remarks
  – MSC Apex
  – Extension to MSC One
INTRODUCTIONS
TEN TECH LLC & MSC Apex

"TEN TECH LLC assists Aerospace & Defense companies in designing better, safer products faster and at a reduced cost."
William VILLERS

• Co-Founder, CTO & Director of TEN TECH LLC
  – Manage Technical Aspects of the Company
  – Project Management & Customer Relations
  – Analysis Team Management

• Seasoned Aerospace & Defense Professional
  – MSME & ABD Doctor of Engineering, MIT France
  – 25 years of Industry Experience in EU & US
    • Engineering & Engineering Management
    • Eurocopter, Aerospatiale, EDS
TEN TECH LLC Services & Solutions

• Aerospace & Defense Design, Test & Analysis Consultants
  – ITAR-Registered Woman Owned Small Business
  – Cage Code Holder, Active DD-2345 DoD Certification
  – Offices in Los Angeles, CA and Billerica, MA

• Modeling & Simulation Subject Matter Experts
  – Rugged Electronics, RF & Microwave Components
  – Structural Dynamics, Shock & Vibration
  – Thermal Design & Electronics Cooling
Expertise & Industry Distribution

- Naval: 20%
- Medical: 1%
- Energy: 1%
- Industrial: 3%
- Transportation: 1%
- Space: 7%
- CP&R: 2%
- Defense Electronics: 65%
- Shock & Vibration: 65%
- Thermal & CFD: 17%
- Vibro-Acoustics: 1%
- Stress: 13%
- CAE Training: 3%
- Test Planning: 1%
MSC Software

- Worldwide Leader in Multi-discipline Simulation Software
  - One of the 10 Original Software Companies
  - Awarded the Original NASA Nastran Contract in 1965

- Vast Portfolio of Industry-Standard Solvers
  - Nastran, Adams, Marc, Sinda, Actran

- Redefining CAE Process with MSC Apex
  - World’s First Computational Parts Based CAE System
  - High-performance Meshers & Integrated Structural Solver
MSC Apex CAE Platform

- Easy to Learn, Easy to Use
  - Achieve Proficiency in Hours vs. Weeks

- CAE-specific Direct Modeling & Meshing
  - Geometry Abstraction & Simplification
  - High-performance Mesher

- Integrated & Generative Solver
  - Incremental Solver Methods
  - Computational Parts & Assemblies
Structural Analysis with Computational Parts

- **Analysis Results Stored at Part Level**
  - Allows for Incremental Model Validation
  - Speeds Up Assembly Analysis
    - Assembly of Results vs Results of Assembly
  - Speeds Up Design Changes Reanalysis
    - Only Changes are Processed
    - Faster Matrix Reassembly

- **Average 2.5x Faster than First Solve**
  - Often 10x depending on the solution
CubeSat Analysis with MSC Apex
Requirements, Environments, Finite Element Analysis
CubeSat Standard Design & Qualification

- Cal-Poly SLO CubeSat Design Specification
  - Mechanical, Electrical, Operational Requirements
  - Protoflight & Acceptance Testing Requirements

- NASA Goddard Space Flight Center GSFC-STD-7000
  - General Environmental Verification Standard
  - Modal Survey, Structural Loads, Sine Vibration, Shock
CAD Geometry As Analysis Starting Point

- Direct Import of Native CAD Assembly
  - SolidWorks, CATIA, NX, Pro/E,…
  - Retention of Product Structure
  - Geometry, Positioning

- Feature Suppression & Abstraction
  - Removal of Small Feature
  - Direct Modeling Operations
Mesh Creation

- **Automated TET & Brick Meshing**
  - Detailed Modeling of Electronics

- **Disjoint Meshes Connections**
  - Nastran Glue Joint

- **Semi-Automatic Fastener Connections**
  - Rigid & Beams Combination
  - Recovery of Fastener Loads
Modal Survey

• Classic Modal Analysis
  – Rigid Body Modes
  – Constrained Modes
  – Range of Interest [0,2000Hz]

• Dynamics Characterization
  – Resonant Frequencies
  – Dominant Modes
  – Mass Participation Factors

\[
\Gamma_n = \frac{I_n}{M_n} = \frac{\{\phi_n\}^T \{m\} \{t\} \{\phi_n\}}{\{\phi_n\}^T \{m\} \{\phi_n\}}
\]
Quasi-Static Acceleration Analysis

- Acceleration Equivalence to Shock & Vibration
  - Conservative, First-pass Evaluation
  - Dependent on Modal Analysis
  - Shock Pulse using Harris Formula
  - Random with Miles’ Equation

\[
A_{eq}(\omega_n, 0) = \frac{1}{g} \left( \frac{2(\omega_n \tau / \pi)}{1 - (\omega_n \tau / \pi)^2} \right) \cos \left( \frac{\omega_n \tau}{2} \right) \\
A_{eq}^\pm(\omega_n, 0) = \frac{1}{g} \left( \frac{(\omega_n \tau / \pi)}{(\omega_n \tau / \pi) - 1} \right) \sin \left( \frac{2i\pi}{(\omega_n \tau / \pi) + 1} \right)
\]

\[
\begin{align*}
\omega_n &\leq \frac{\pi}{\tau} \\
\omega_n &> \frac{\pi}{\tau}
\end{align*}
\]
Dynamics Response

- **Modal Analysis + Modal Response**
  - Time & Frequency Domain
  - Modal Truncation & Residual Vectors
  - Modal & Structural Damping
  - Stress Stiffening & Inertia Relief

- **Traditional Response Output**
  - Transmissibility & Transfer Functions
  - Modal Contribution
  - Peak Stress, Displacements, Accelerations, Forces
Bolted Joints Calculations

- NASA-STD-5020 & NASA TM-106943
  - Recovery of Fastener Forces
  - Joint Separation & Slippage
  - Combined Bolt Tension, Shear, Bending
  - Bolts Thread Shear
Electronics Components Vibration Fatigue

- “Steinberg” Approach to Fatigue
  - Based on FEA Board Deflection

\[ Z_{3\sigma \text{ limit}} = \frac{0.00022 \times B}{Chr \sqrt{L}} \] (20 million cycles)

- **B**: length of the circuit board edge parallel to the component, inches
- **L**: length of the electronic component, inches
- **h**: circuit board thickness, inches
- **r**: relative position factor for the component mounted on the board
- **C**: Constant for different types of electronic components
  \[ 0.75 \leq C \leq 2.25 \]
Closing Remarks

Conclusions, Q&A
Conclusions

- **Fast Design Validation with MSC Apex**
  - Fast Model Creation from Native Geometry
  - Good Breath of Structural Analysis Solvers
  - Computational Parts Save A Lot of Time

- **Scalable via MSC One Token System**
  - Reuse of Apex Model for Downstream Applications
  - Nastran Random Vibration Fatigue
  - Sinda/Thermica Orbital Thermal Analysis
  - Actran Vibro-Acoustics Analysis
For More Information

- Website: https://www.tentechllc.com
- Facebook Page: https://www.facebook.com/tentechllc
- YouTube Channel: https://www.youtube.com/user/TenTechLLC
- Twitter Page: https://twitter.com/TENTECHLLC
- LinkedIn Page: https://www.linkedin.com/company/ten-tech-llc