# ASD/CLAS

-

# Multibody Dynamic Analysis Software

Arya Majed, Ph.D.
Chief, Structural Dynamics/Advanced Methods
Applied Structural Dynamics, Inc.
Arya.Majed@AppliedStructuralDynamics.com
713.468.5966

Kevin Partin
Chief, Computational Methods
Applied Structural Dynamics, Inc.
Kevin.Partin@AppliedStructuralDynamics.com
281.286.8959

ASD-TB-10-011-R2
Updated: 10/20/2010



Applied Structural Dynamics, Inc.

# Introduction

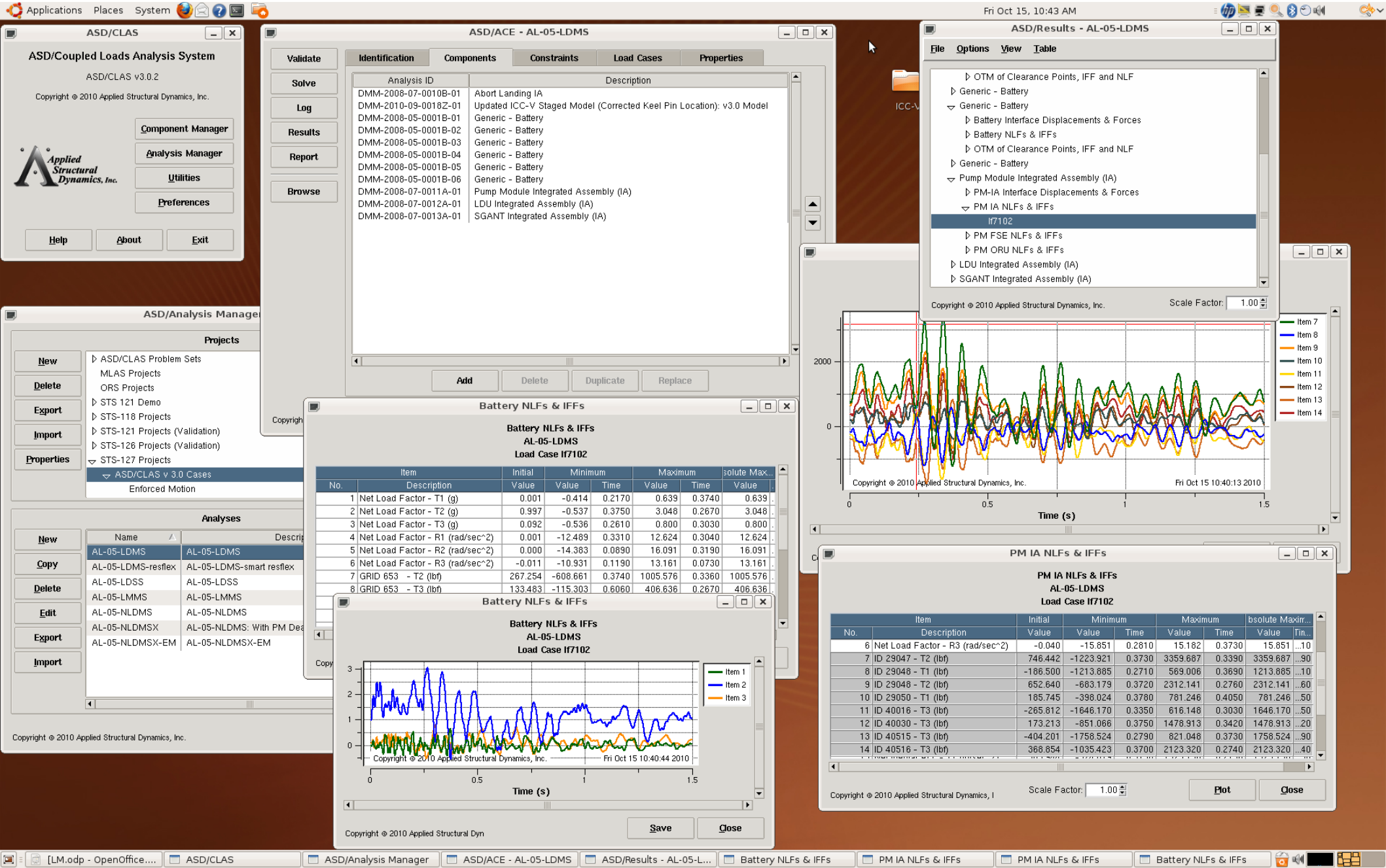
- ASD/CLAS is an integrated, user-friendly multibody software tool for highly efficient and accurate dynamic analysis of systems of structural  dynamic math models
  - Example application: launch vehicle/payloads coupled loads analysis (CLA)
- Utilized by major contractors for the execution of design, sensitivity/trade studies, and mission critical linear and nonlinear coupled loads analyses (CLAs)
  - e.g., Shuttle/payloads linear and nonlinear transient CLAs
- Developed and maintained by ASD and available for leasing



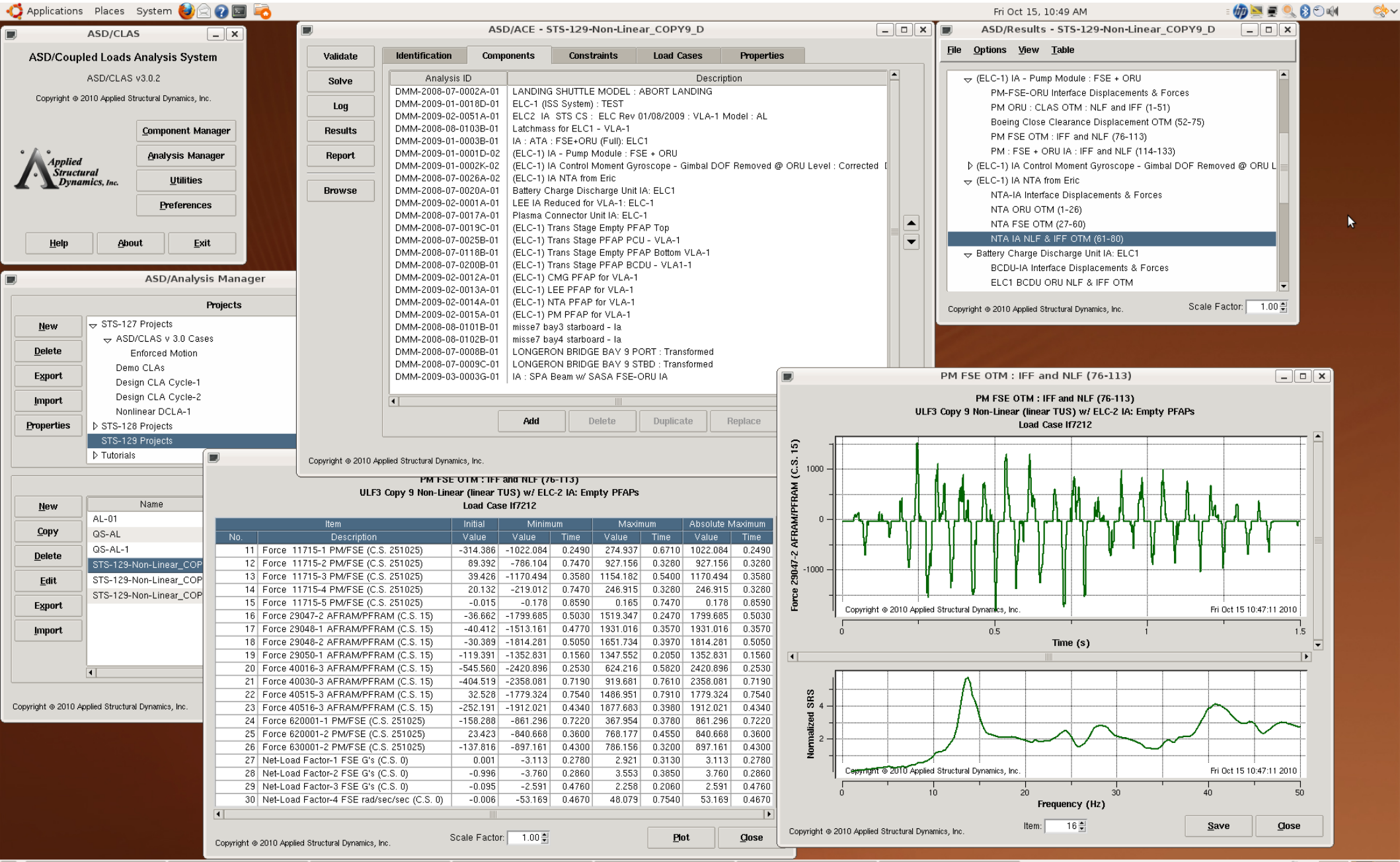


Applied Structural Dynamics, Inc.

# Snapshot of an ASD/CLAS Session:
## Linear Coupled Loads Analysis



# Snapshot of an ASD/CLAS Session:
## Nonlinear Coupled Loads Analysis



# Proven Significant CLA Schedule Reductions

- Launch vehicle CLA cycles often called the “long pole in the tent” in design/analysis/certification of space flight hardware
- The enabling technologies in ASD/CLAS have resulted in drastic reductions in the schedule templates required for CLAs
  - CLA schedule reductions of 90% or better
- The schedule gains are utilized to conduct linear/nonlinear CLAs for various risk mitigation sensitivity, trade studies and mission critical analyses
  - High recognition/praise from the NASA customer

# Selected for Space Shuttle/Payloads Nonlinear CLAs

- ASD/CLAS has the distinction of being selected by the NASA/JSC for the performance of all mission critical Space Shuttle/payloads nonlinear CLAs
  - Only tool that consistently produces physically realizable nonlinear time-histories, free of numerical chatter/noise, that conform to the physical parameters and constraints defined in the analyses
    - Lockheed Martin successfully conducting over 20 Space Shuttle/ Payloads nonlinear CLAs for their NASA customer
      - Including Space Shuttle Mission ULF-3 which included 40+ nonlinear components and 400+ interface and internal component deadbands

# ASD/CLAS Key Benefits

- Intelligent/intuitive graphical user interfaces that expedite analysis setups, execution, analysis review and report generation
- Automated configuration management over all data and analyses
- Significantly simplifies and expedites the CLA process
- Enables a highly synergistic design/analysis process
- Expedites trade/sensitivity studies utilizing full CLAs instead of approximate methods
- Enables expedited, highly accurate nonlinear CLAs
- Allows the entire analysis team to share data and analyses
- Drastically shortens analyst training times even on the most complex nonlinear CLAs
- Supports the entire analysis process from configuration management to analysis set-up, execution, review, and customer report generation
- Eliminates the most common sources of CLA difficulties and errors

# ASD/CLAS Key Features

- Intelligent/Intuitive Graphical User Interfaces
  - Easy analysis setups/fast learning curves
  - Provides the user with lots of flexibility/options
- Automated Configuration Management
  - Prevents models/data that are not under configuration management or have not been checked from entering the analysis
  - Enables entire team to share data/analyses





Applied Structural Dynamics, Inc.

# ASD/CLAS Key Features – Cont'd

- Automated Analysis Bookkeeping
  - Eliminates the tedious, schedule-intensive, error-prone task of user manual bookkeeping
- Multibody
  - Enables easy addition/deletion of components from analysis
  - Circumvents the need for upstream component integrations
  - Enables robust nonlinear dynamic analysis

# ASD/CLAS Key Features – Cont'd

- Proven/Robust Analysis Modules
  - ASD/Check: Comprehensive mathematical check module: conducts checks on dynamic math models and associated output transformation matrices
  - ASD/CMS: Component-mode synthesis (CMS) module: provides efficient CMS and dynamic math model reduction capabilities (all methods)
  - ASD/CLA: Linear coupled loads analysis (CLA) module: provides the capability for highly efficient multibody linear CLAs; direct and modal solutions; system and component damping options; single and multi-step integrators; powerful linear constraint equation logic includes coordinate transformations, rigid constraints, multi-point constraints, soft

# ASD/CLAS Key Features – Cont'd

- Proven/Robust Analysis Modules (Cont'd)
  - ASD/VCLA: Variational CLA module: leverages the ASD/CLAS expedited CLA turnarounds with the capability to conduct automated sensitivity analyses allowing variations in component parameters such as stiffness, frequency, mass, damping, ...
  - ASD/NCLA: Nonlinear CLA module: provides for highly efficient multibody nonlinear CLAs; nonlinearities introduced easily utilizing nonlinear constraint equations; nonlinearities include two-sided deadbands, one-sided deadbands, foam, straps, snubbers, nonlinear springs, ...

# ASD/CLAS Key Features – Cont'd

- Proven/Robust Analysis Modules (Cont'd)
  - ASD/EM: Enforced motion module: provides the capability to conduct highly efficient multibody linear/nonlinear enforced motion analysis
  - ASD/PadSep (module in work): Pad separation module: provides the capability of enforcing “response dependent” constraint equations in multibody systems to simulate transient events such as launch vehicle pad separation and staging

# ASD/CLAS Key Features – Cont'd

- Proven/Robust Analysis Modules
  - ASD/RV (module in work): Random vibrations module (in work): provides the capability for highly efficient multibody frequency domain and random vibration analyses





Applied Structural Dynamics, Inc.

# ASD/CLAS Key Features – Concluded

- Graphical Results Reviewer
  - Enables quick and comprehensive review over ALL CLA max/min tables, time-histories, response spectra
- Automatic Report Generator
  - Automatically generates report appendices
- Custom Report Generator
  - Enables quick preparation of custom reports with multiple analysis appendices and comparison tables





Applied Structural Dynamics, Inc.

# Client Testimonials

*"We had tried other commercially available tools in the past to solve this type of nonlinear CLA problem. Even with just a few deadbands, the solution time-histories were riddled with numerical noise, rendering the results useless for our purposes. ASD/CLAS solved this very difficult problem with no issues producing very rational response time-histories. In addition, ASD/CLAS's results viewer allowed us to quickly go through all component and OTM time-histories and its custom report generator allowed us to quickly generate the required comparison tables for our customers. All this was done in ASD/CLAS's user friendly, configuration managed environment."*

*S. V., Engineering Analysis Manager and Technical Fellow, Lockheed Martin Corporation*

*"ASD/CLAS software tool ... easily surpasses anything in the industry right now"*

*T. C., East Coast Operations Manager, Oceaneering Space Systems*

*"A very impressive capability. Easy to learn and use. Takes all the trouble out of component mode synthesis."*

*P. G., Lead Engineer, Loads & Dynamics, Teledyne-Brown Corporation*





Applied Structural Dynamics, Inc.

# Client Testimonials – Cont'd

*"We selected ASD/CLAS based on its ability to eliminate the various complexities associated with the coupled loads analysis process. With this capability, we can drive our design process in lock-step with our analysis process, providing the design team with loads updates as the design evolves and quickly converging to an optimized design (weight savings) that meets all structural requirements. ASD/CLAS is an impressive and as advertised capability. Also, ASD provided excellent training. Our team was ready to conduct coupled loads analysis after the morning session."*

*T. C., East Coast Operations Manager, Oceaneering Space Systems*

*"By the way, we just finished doing a last minute CLA for the upcoming 19A launch, finishing a mere six days before the planned launch. Just five days from receiving mass properties data to delivering results. That included building two integrated MPLM CMS models to get mass participation data plus setting up and running a landing CLA and associated report. And two of those days were used developing rack models. Couldn't have done it without your product."*

*P. G., Lead Engineer, Loads & Dynamics, Teledyne-Brown Corporation*





Applied Structural Dynamics, Inc.

# Client Testimonials – Concluded

*"In the Lockheed Martin Corporation's support to the NASA Space Shuttle cargo integration function, I was recently tasked to execute a mission specific nonlinear coupled load analysis, the nonlinearities consisting of ISS component interface dead-bands, i.e., rattle space at interfacing attach points between major hardware elements to be delivered to the International Space Station. This NASA risk mitigation task was successfully completed and was only enabled by Lockheed Martin's use of Applied Structural Dynamics' Coupled Loads Analysis System, ASD/CLAS.*

*From my prospective, having used many tools with nonlinear capabilities, ASD/CLAS was not only the easiest of all of the tools to implement, but the only tool I've seen to produce dead-band transient results that matches the physical characteristics/limitations of the phenomena. The resulting time histories, forces, and motion across the dead-band gap, exhibit a beautiful adherence to the physical limitations that define the nonlinear interfaces.*

*ASD/CLAS is a proven asset to my NASA flight support function. It has brought praise from our NASA customer. It excels over all other tools I've seen, in both linear and nonlinear coupled loads analyses."*

*S. B., Lead Engineer, Loads & Dynamics, Lockheed Martin Corporation*





Applied Structural Dynamics, Inc.

# Summary

- Significantly simplifies and expedites the CLA process
- Maintains all math models and analyses under a robust configuration management system
- Enables a simplified and highly synergistic design/analysis process
- Enables cost-effective, expedited variational CLAs
- Enables cost-effective, expedited nonlinear CLAs
- Eliminates the most common sources of CLA difficulties and errors

The above translates into significant reductions in design and mission **cost**, **schedule**, and **risk** coupled with significant increases in **productivity**





Applied Structural Dynamics, Inc.