

ASD/CLAS

-

Multibody Dynamic Analysis Software

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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

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

Applications Places System Fri Oct 15, 10:43 AM

ASD/CLAS

ASD/Coupled Loads Analysis System

ASD/CLAS v3.0.2

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Component Manager

Analysis Manager

Utilities

Preferences

Help About Exit

ASD/ACE - AL-05-LDMS

Validate Solve Log Results Report Browse

Identification	Components	Constraints	Load Cases	Properties
Analysis ID	Description			
DMM-2008-07-0010B-01	Abort Landing IA			
DMM-2010-09-0018Z-01	Updated ICC-V Staged Model (Corrected Keel Pin Location): v3.0 Model			
DMM-2008-05-0001B-01	Generic - Battery			
DMM-2008-05-0001B-02	Generic - Battery			
DMM-2008-05-0001B-03	Generic - Battery			
DMM-2008-05-0001B-04	Generic - Battery			
DMM-2008-05-0001B-05	Generic - Battery			
DMM-2008-05-0001B-06	Generic - Battery			
DMM-2008-07-0011A-01	Pump Module Integrated Assembly (IA)			
DMM-2008-07-0012A-01	LDU Integrated Assembly (IA)			
DMM-2008-07-0013A-01	SGANT Integrated Assembly (IA)			

Add Delete Duplicate Replace

ASD/Results - AL-05-LDMS

File Options View Table

- ▶ OTM of Clearance Points, IFF and NLF
- ▶ Generic - Battery
- ▼ Generic - Battery
 - ▶ Battery Interface Displacements & Forces
 - ▶ Battery NLFs & IFFs
 - ▶ OTM of Clearance Points, IFF and NLF
- ▶ Generic - Battery
- ▼ Pump Module Integrated Assembly (IA)
 - ▶ PM-IA Interface Displacements & Forces
 - ▼ PM IA NLFs & IFFs
 - IF7102**
 - ▶ PM FSE NLFs & IFFs
 - ▶ PM ORU NLFs & IFFs
 - ▶ LDU Integrated Assembly (IA)
 - ▶ SGANT Integrated Assembly (IA)

Scale Factor: 1.00

ASD/Analysis Manager

New Projects

- ▶ ASD/CLAS Problem Sets
- MLAS Projects
- ORS Projects
- ▶ STS 121 Demo
- ▶ STS-118 Projects
- ▶ STS-121 Projects (Validation)
- ▶ STS-126 Projects (Validation)
- ▼ STS-127 Projects
 - ▼ ASD/CLAS v 3.0 Cases
 - Enforced Motion

Analyses

Name	Description
AL-05-LDMS	AL-05-LDMS
AL-05-LDMS-resflex	AL-05-LDMS-smart reflex
AL-05-LDSS	AL-05-LDSS
AL-05-LMMS	AL-05-LMMS
AL-05-NLDMS	AL-05-NLDMS
AL-05-NLDMSX	AL-05-NLDMS: With PM Dec
AL-05-NLDMSX-EM	AL-05-NLDMSX-EM

Copy Delete Edit Export Import

Battery NLFs & IFFs

AL-05-LDMS

Load Case IF7102

No.	Item	Description	Initial Value	Minimum Value	Time	Maximum Value	Time	bsolute Max...
1	Net Load Factor - T1 (g)		0.001	-0.414	0.2170	0.639	0.3740	0.639
2	Net Load Factor - T2 (g)		0.997	-0.537	0.3750	3.048	0.2670	3.048
3	Net Load Factor - T3 (g)		0.092	-0.536	0.2610	0.800	0.3030	0.800
4	Net Load Factor - R1 (rad/sec^2)		0.001	-12.489	0.3310	12.624	0.3040	12.624
5	Net Load Factor - R2 (rad/sec^2)		0.000	-14.383	0.0890	16.091	0.3190	16.091
6	Net Load Factor - R3 (rad/sec^2)		-0.011	-10.931	0.1190	13.161	0.0730	13.161
7	GRID 653 - T2 (lbf)		267.254	-608.661	0.3740	1005.576	0.3360	1005.576
8	GRID 653 - T3 (lbf)		133.483	-115.303	0.6060	406.636	0.2670	406.636

Time (s)

Battery NLFs & IFFs

AL-05-LDMS

Load Case IF7102

Time (s)

Save Close

PM IA NLFs & IFFs

AL-05-LDMS

Load Case IF7102

No.	Item	Description	Initial Value	Minimum Value	Time	Maximum Value	Time	bsolute Maxir...
6	Net Load Factor - R3 (rad/sec^2)		-0.040	-15.851	0.2810	15.182	0.3730	15.851
7	ID 29047 - T2 (lbf)		746.442	-1223.921	0.3730	3359.687	0.3390	3359.687
8	ID 29048 - T1 (lbf)		-186.500	-1213.885	0.2710	569.006	0.3690	1213.885
9	ID 29048 - T2 (lbf)		652.640	-683.179	0.3720	2312.141	0.2760	2312.141
10	ID 29050 - T1 (lbf)		185.745	-398.024	0.3780	781.246	0.4050	781.246
11	ID 40016 - T3 (lbf)		-265.812	-1646.170	0.3350	616.148	0.3030	1646.170
12	ID 40030 - T3 (lbf)		173.213	-851.066	0.3750	1478.913	0.3420	1478.913
13	ID 40515 - T3 (lbf)		-404.201	-1758.524	0.2790	821.048	0.3730	1758.524
14	ID 40516 - T3 (lbf)		368.854	-1035.423	0.3700	2123.320	0.2740	2123.320

Scale Factor: 1.00

Plot Close

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Taskbar: [LM.odp - OpenOffice...] ASD/CLAS ASD/Analysis Manager ASD/ACE - AL-05-LDMS ASD/Results - AL-05-L... Battery NLFs & IFFs PM IA NLFs & IFFs PM IA NLFs & IFFs Battery NLFs & IFFs

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

Applications Places System

Fri Oct 15, 10:49 AM

ASD/CLAS

ASD/Coupled Loads Analysis System

ASD/CLAS v3.0.2

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Component Manager

Analysis Manager

Utilities

Preferences

Help About Exit

ASD/Analysis Manager

Projects

- New
- Delete
- Export
- Import
- Properties

- STs-127 Projects
 - ASD/CLAS v 3.0 Cases
 - Enforced Motion
 - Demo CLAs
 - Design CLA Cycle-1
 - Design CLA Cycle-2
 - Nonlinear DCLA-1
- STs-128 Projects
- STs-129 Projects
- Tutorials

New

Copy

Delete

Edit

Export

Import

Name
AL-01
QS-AL
QS-AL-1
STs-129-Non-Linear_COP
STs-129-Non-Linear_COP
STs-129-Non-Linear_COP

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ASD/ACE - STS-129-Non-Linear_COPY9_D

Validate Solve Log Results Report Browse

Identification	Components	Constraints	Load Cases	Properties
Analysis ID	Description			
DMM-2008-07-0002A-01	LANDING SHUTTLE MODEL : ABORT LANDING			
DMM-2009-01-0018D-01	ELC-1 (ISS System) : TEST			
DMM-2009-02-0051A-01	ELC2 IA STS CS : ELC Rev 01/08/2009 : VLA-1 Model : AL			
DMM-2008-08-0103B-01	Latchmass for ELC1 - VLA-1			
DMM-2009-01-0003B-01	IA : ATA : FSE+ORU (Full): ELC1			
DMM-2009-01-0001D-02	(ELC-1) IA - Pump Module : FSE + ORU			
DMM-2009-01-0002K-02	(ELC-1) IA Control Moment Gyroscope - Gimbal DOF Removed @ ORU Level : Corrected			
DMM-2008-07-0026A-02	(ELC-1) IA NTA from Eric			
DMM-2008-07-0020A-01	Battery Charge Discharge Unit IA: ELC1			
DMM-2009-02-0001A-01	LEE IA Reduced for VLA-1: ELC-1			
DMM-2008-07-0017A-01	Plasma Connector Unit IA: ELC-1			
DMM-2008-07-0019C-01	(ELC-1) Trans Stage Empty PFAP Top			
DMM-2008-07-0025B-01	(ELC-1) Trans Stage PFAP PCU - VLA-1			
DMM-2008-07-0118B-01	(ELC-1) Trans Stage Empty PFAP Bottom VLA-1			
DMM-2008-07-0200B-01	(ELC-1) Trans Stage PFAP BCDU - VLA-1-1			
DMM-2009-02-0012A-01	(ELC-1) CMG PFAP for VLA-1			
DMM-2009-02-0013A-01	(ELC-1) LEE PFAP for VLA-1			
DMM-2009-02-0014A-01	(ELC-1) NTA PFAP for VLA-1			
DMM-2009-02-0015A-01	(ELC-1) PM PFAP for VLA-1			
DMM-2008-08-0101B-01	misse7 bay3 starboard - Ia			
DMM-2008-08-0102B-01	misse7 bay4 starboard - Ia			
DMM-2008-07-0008B-01	LONGERON BRIDGE BAY 9 PORT : Transformed			
DMM-2008-07-0009C-01	LONGERON BRIDGE BAY 9 STBD : Transformed			
DMM-2009-03-0003G-01	IA : SPA Beam w/ SASA FSE-ORU IA			

Add Delete Duplicate Replace

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ASD/Results - STS-129-Non-Linear_COPY9_D

File Options View Table

- (ELC-1) IA - Pump Module : FSE + ORU
 - PM-FSE-ORU Interface Displacements & Forces
 - PM ORU : CLAS OTM : NLF and IFF (1-51)
 - Boeing Close Clearance Displacement OTM (52-75)
 - PM FSE OTM : IFF and NLF (76-113)
 - PM : FSE + ORU IA : IFF and NLF (114-133)
- (ELC-1) IA Control Moment Gyroscope - Gimbal DOF Removed @ ORU L
 - (ELC-1) IA NTA from Eric
 - NTA-IA Interface Displacements & Forces
 - NTA ORU OTM (1-26)
 - NTA FSE OTM (27-60)
 - NTA IA NLF & IFF OTM (61-80)
 - Battery Charge Discharge Unit IA: ELC1
 - BCDU-IA Interface Displacements & Forces
 - ELC1 BCDU ORU NLF & IFF OTM

Scale Factor: 1.00

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PM FSE OTM : IFF and NLF (76-113)

ULF3 Copy 9 Non-Linear (linear TUS) w/ ELC-2 IA: Empty PFAPs

Load Case I7212

No.	Item	Description	Initial Value	Minimum Value	Time	Maximum Value	Time	Absolute Maximum Value	Time
11	Force	11715-1 PM/FSE (C.S. 251025)	-314.386	-1022.084	0.2490	274.937	0.6710	1022.084	0.2490
12	Force	11715-2 PM/FSE (C.S. 251025)	89.932	-786.104	0.7470	927.156	0.3280	927.156	0.3280
13	Force	11715-3 PM/FSE (C.S. 251025)	39.426	-1170.494	0.3580	1154.182	0.5400	1170.494	0.3580
14	Force	11715-4 PM/FSE (C.S. 251025)	20.132	-219.012	0.7470	246.915	0.3280	246.915	0.3280
15	Force	11715-5 PM/FSE (C.S. 251025)	-0.015	-0.178	0.8590	0.165	0.7470	0.178	0.8590
16	Force	29047-2 AFRAM/PFRAM (C.S. 15)	-36.662	-1799.685	0.5030	1519.347	0.2470	1799.685	0.5030
17	Force	29048-1 AFRAM/PFRAM (C.S. 15)	-40.412	-1513.161	0.4770	1931.016	0.3570	1931.016	0.3570
18	Force	29048-2 AFRAM/PFRAM (C.S. 15)	-30.389	-1814.281	0.5050	1651.734	0.3970	1814.281	0.5050
19	Force	29050-1 AFRAM/PFRAM (C.S. 15)	-119.391	-1352.831	0.1560	1347.552	0.2050	1352.831	0.1560
20	Force	40016-3 AFRAM/PFRAM (C.S. 15)	-545.560	-2420.896	0.2530	624.216	0.5820	2420.896	0.2530
21	Force	40030-3 AFRAM/PFRAM (C.S. 15)	-404.519	-2358.081	0.7190	919.681	0.7610	2358.081	0.7190
22	Force	40515-3 AFRAM/PFRAM (C.S. 15)	32.528	-1779.324	0.7540	1486.951	0.7910	1779.324	0.7540
23	Force	40516-3 AFRAM/PFRAM (C.S. 15)	-252.191	-1912.021	0.4340	1877.683	0.3980	1912.021	0.4340
24	Force	620001-1 PM/FSE (C.S. 251025)	-158.288	-861.296	0.7220	367.954	0.3780	861.296	0.7220
25	Force	620001-2 PM/FSE (C.S. 251025)	23.423	-840.668	0.3600	768.177	0.4550	840.668	0.3600
26	Force	630001-2 PM/FSE (C.S. 251025)	-137.816	-897.161	0.4300	786.156	0.3200	897.161	0.4300
27	Net-Load Factor-1	FSE G's (C.S. 0)	0.001	-3.113	0.2780	2.921	0.3130	3.113	0.2780
28	Net-Load Factor-2	FSE G's (C.S. 0)	-0.996	-3.760	0.2860	3.553	0.3850	3.760	0.2860
29	Net-Load Factor-3	FSE G's (C.S. 0)	-0.095	-2.591	0.4760	2.258	0.2060	2.591	0.4760
30	Net-Load Factor-4	FSE rad/sec/sec (C.S. 0)	-0.006	-53.169	0.4670	48.079	0.7540	53.169	0.4670

Scale Factor: 1.00

Plot Close

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PM FSE OTM : IFF and NLF (76-113)

ULF3 Copy 9 Non-Linear (linear TUS) w/ ELC-2 IA: Empty PFAPs

Load Case I7212

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Item: 16 Save Close

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[Taskbar: [LM.odp - OpenOffice... ASD/CLAS ASD/Analysis Manager ASD/ACE - STS-129-N... ASD/Results - STS-12... PM FSE OTM : IFF and ... PM FSE OTM : IFF and ...]

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

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

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

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

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

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

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**