ASD/CLAS Variational Coupled Loads Analysis Capability
-
Impact of Component Parameter Uncertainties on Coupled Loads Analysis Results

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Background

- Variational (parametric) Coupled Loads Analyses (CLA) are the most accurate means to ascertain the impact of component parameter variations (uncertainties) on component loads
  - An important risk-mitigation exercise

- Detailed variational CLAs have historically been impractical given the schedules required by heritage commercial tools/processes

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Background (Cont'd)

- As a result, risks associated with component parametric variations and nonlinearities are most often treated by approximate means
  - Base-shake analyses
  - Response Spectra Methods
  - Linearizations (valid within a very limited range)
  - Use of "uncertainty factors"

- This briefing addresses the ASD/CLAS Variational CLA capabilities

ASD/CLAS Variational CLA (VCLA)

- Allows for individual component parameter variations
  - Cantilevered frequencies
  - Overall stiffness
  - Boundary stiffness
  - Mass
  - Damping
  - Interface springs and dampers
  - Fluid mass and slosh mass (treated as separate body)
  - Nonlinearities
    - Deadband size
  - Absence, presence or substitution of components
    - Manifest variation

ASD/CLAS VCLA (Cont'd)

- Two variational options
  - Deterministic parameter variation: vary all selected parameter(s) within a user specified range and by a user specified increment, from nominal
  - Probabilistic parameter variation: vary all selected parameters utilizing a uniform or normal statistical distribution
    - Each parameter distribution defined by the analysts
    - Each parameter randomly selected for each CLA
      - Based on parameter's statistical distribution
    - Should produce worst-case loads given enough CLAs conducted in a Variational CLA

Majed, A., Partin, K. S., Henkel, E. E., and Sarafin, T. P., "Variational Coupled Loads Analyses: Reducing Risk in the Development of Space-Flight Hardware," Accepted for publication in *AIAA Journal of Spacecraft and Rockets,* Feb. 2004.

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Application – Mission 1E VCLA

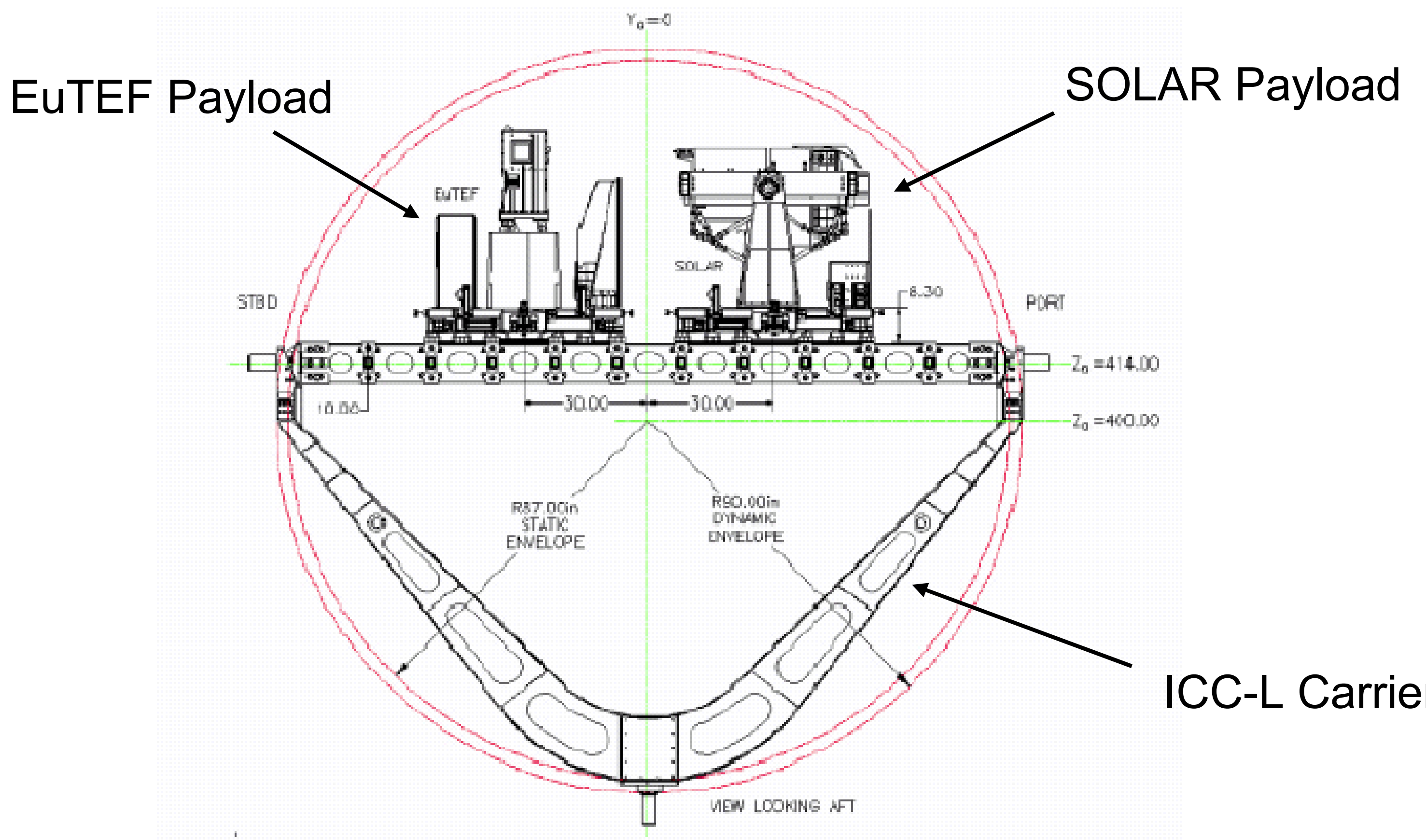
- Purpose: Develop realistic worst case preliminary design loads for the EuTEF and SOLAR payloads manifested on the new carrier ICC-L on Space Shuttle 1E Mission

- Desired to cover variations
  - +/- 20% frequency variations on the EuTEF and SOLAR payloads
  - Multiple possible Orbiter return manifests (5)

- Historical practice due to traditional tools limitations
  - 1 CLA "point" solution times 1.5 Uncertainty Factor (PDR)

- ASD contracted to conduct this Variational CLA (VCLA)
  - +/- 20% frequency variations @ 5% increments in stiffness (19 CLAs per configuration)
  - 1 Liftoff and 5 Landing Configurations (6 x 19 = **114 CLAs**)

ICC-L Configuration for Mission 1E



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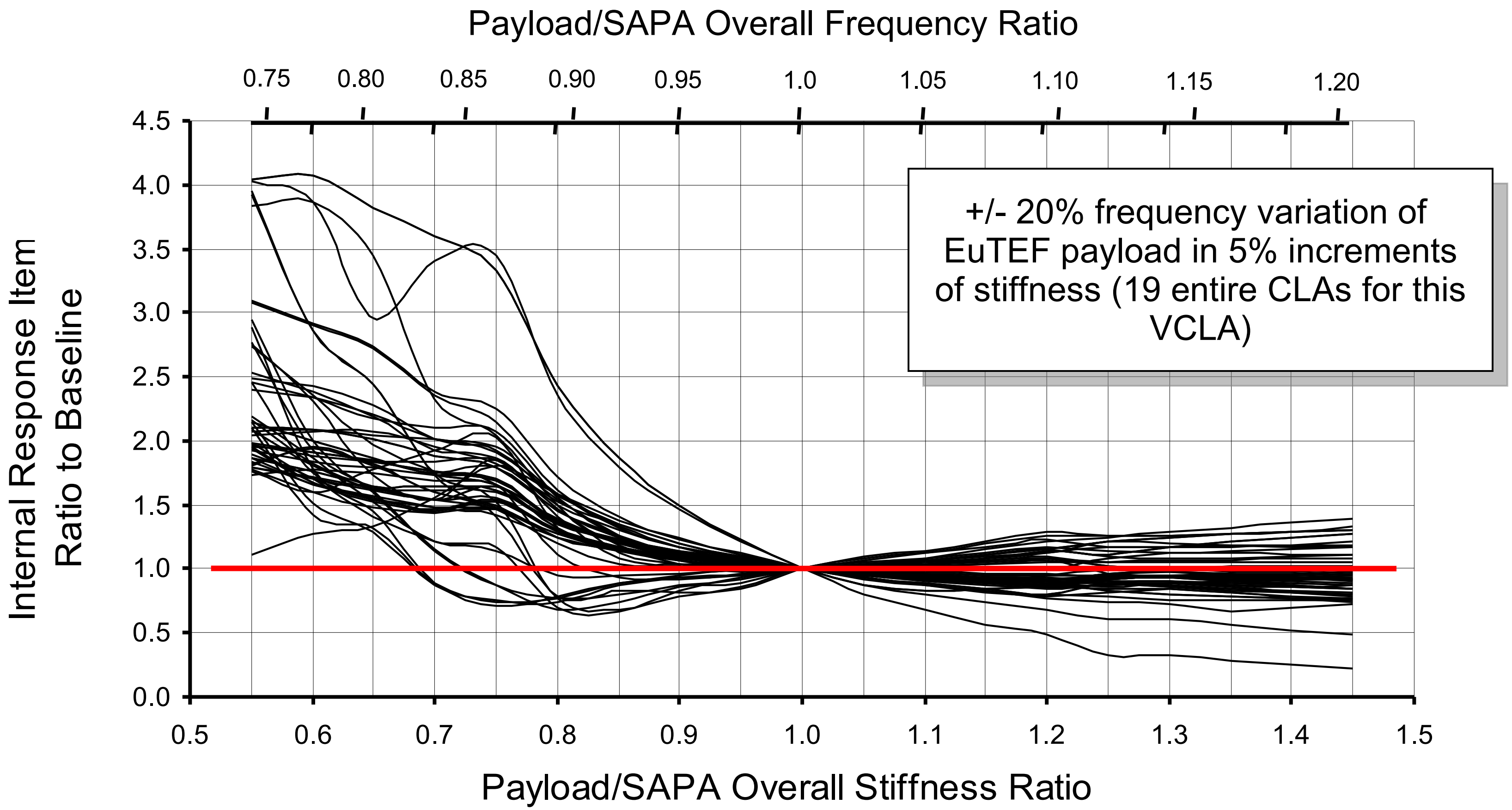
50 <u>Most</u> Sensitive EuTEF Liftoff Internal Recoveries



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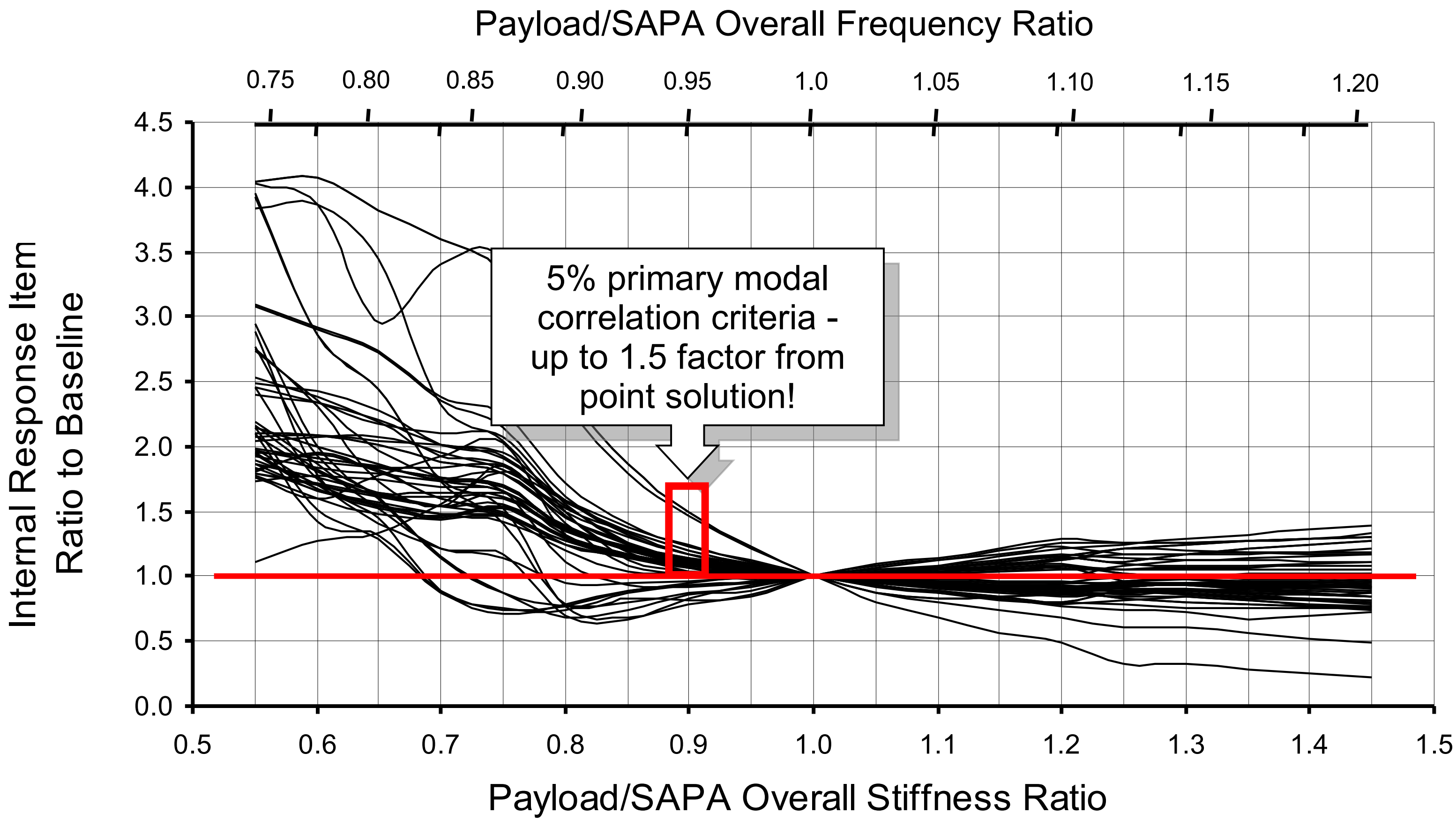
50 Most Sensitive EuTEF Liftoff Internal Recoveries



Component frequency VCLA rigorously capture component structural sensitivities that are significant, even within accepted math model correlation criteria.
This results in **Risk Mitigation**.

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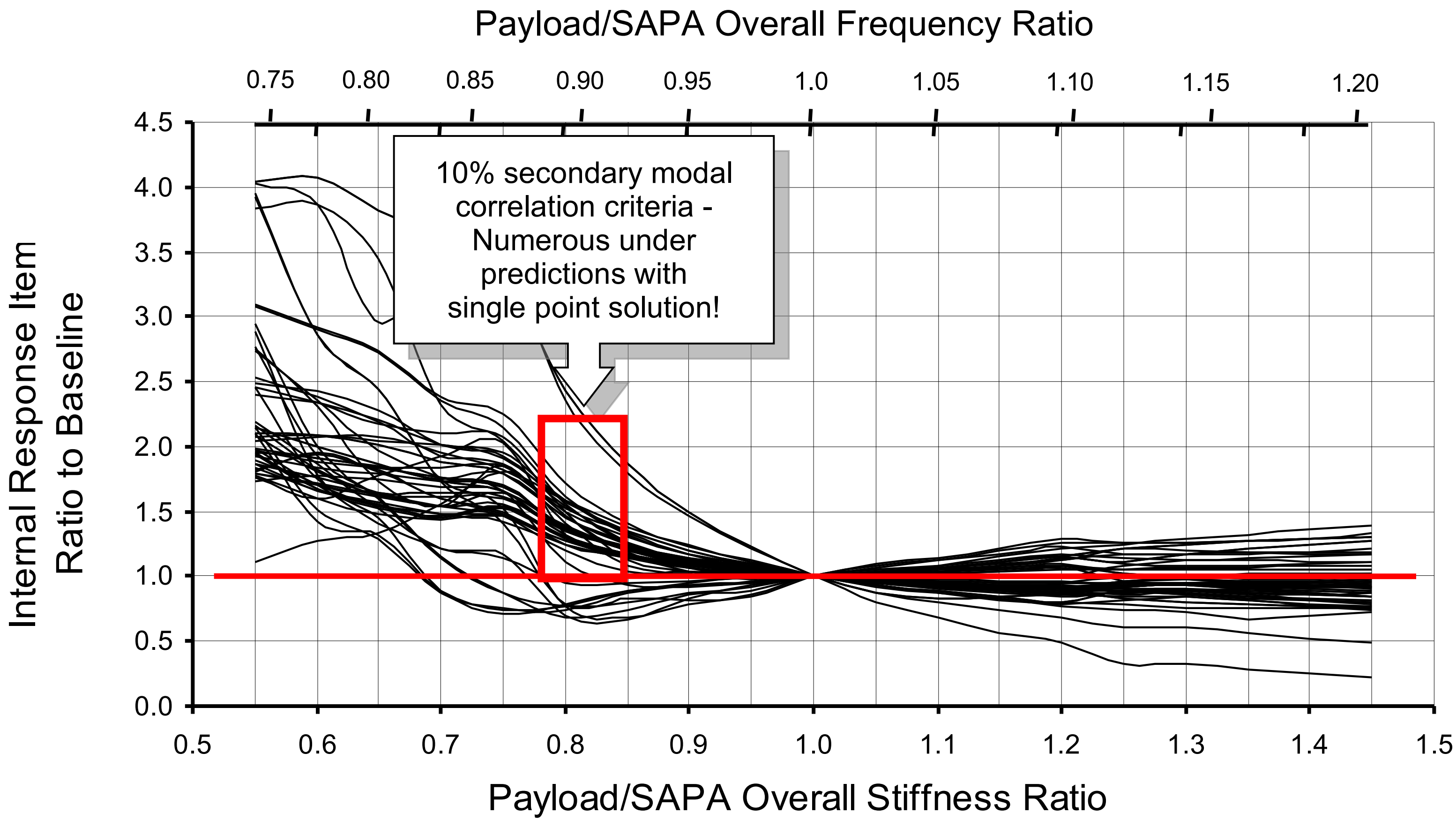

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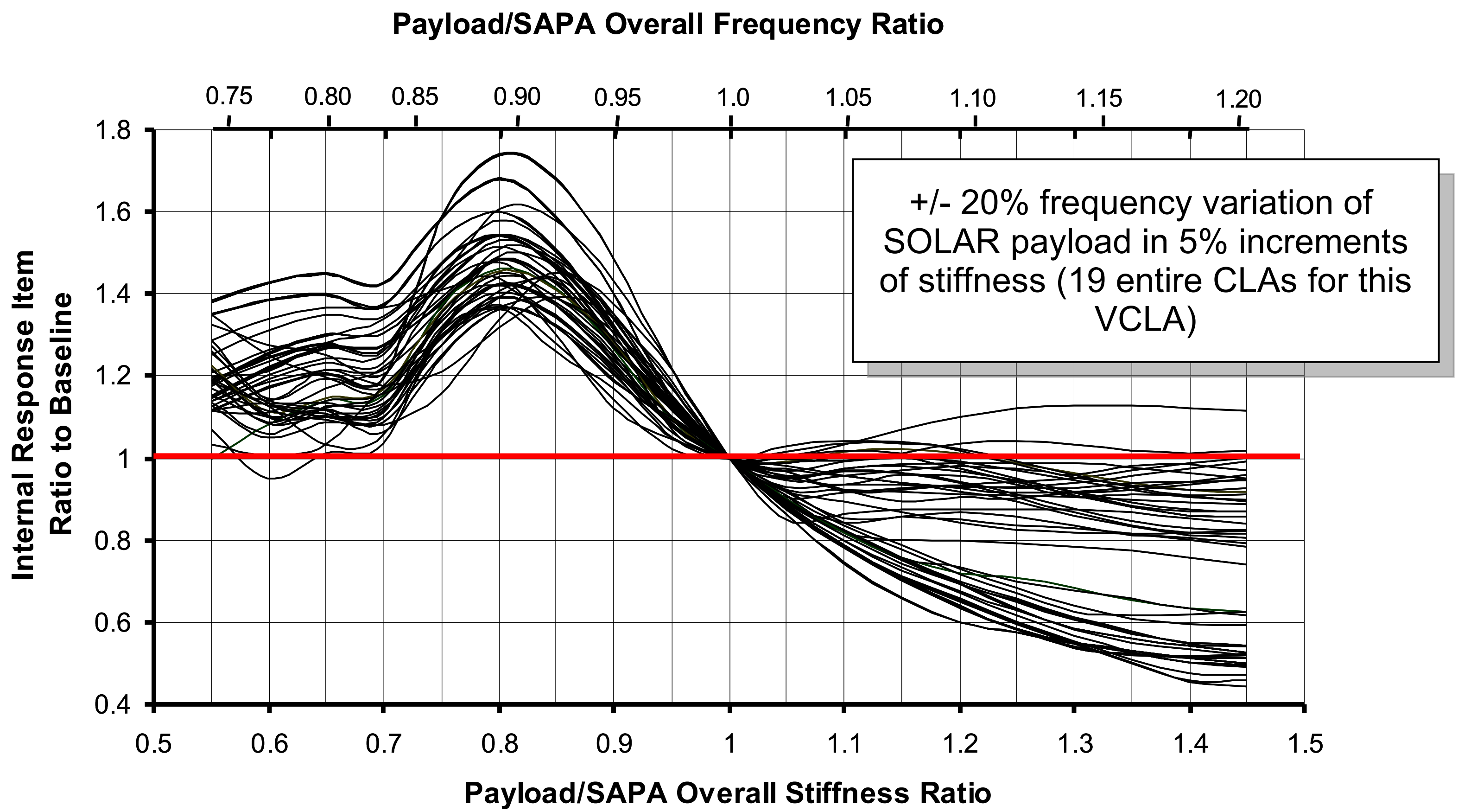
50 <u>Most</u> Sensitive SOLAR Landing Internal Recoveries



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Observations:

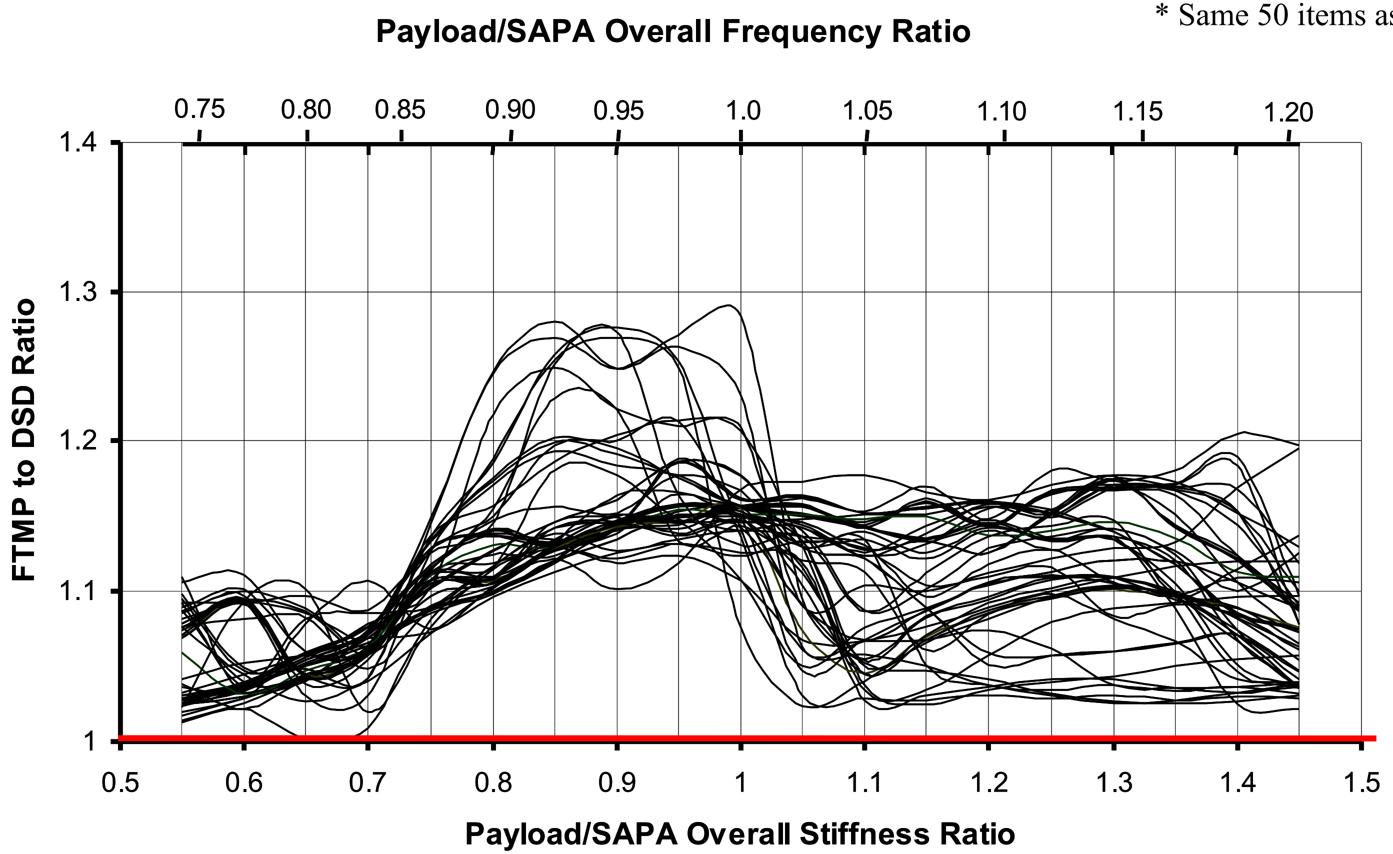
- VCLA demonstrated significant structural response sensitivities
  - Sensitivity to frequency variations of 5% and 10% shown to be significant for individual structural response items

Impact of Damping Approximation – Mission 1E

- ASD/CLAS variational frequency analysis performed with Diagonal System Damping (DSD) and Full Triple Matrix Product (FTMP) damping approximations
  - 1% critical damping utilized for DSD
  - 1% critical component damping utilized for FTMP
- SOLAR payload internal component responses recovered
  - FTMP generally results in <u>higher</u> responses
  - Difference between DSD and FTMP <u>highly</u> coupled to frequency variations

Impact of Damping Approximation - 50 Most Frequency Sensitive SOLAR Landing Internal Recoveries*

* Same 50 items as previous chart



Internal responses' sensitivity to damping approximation highly coupled to component frequency!

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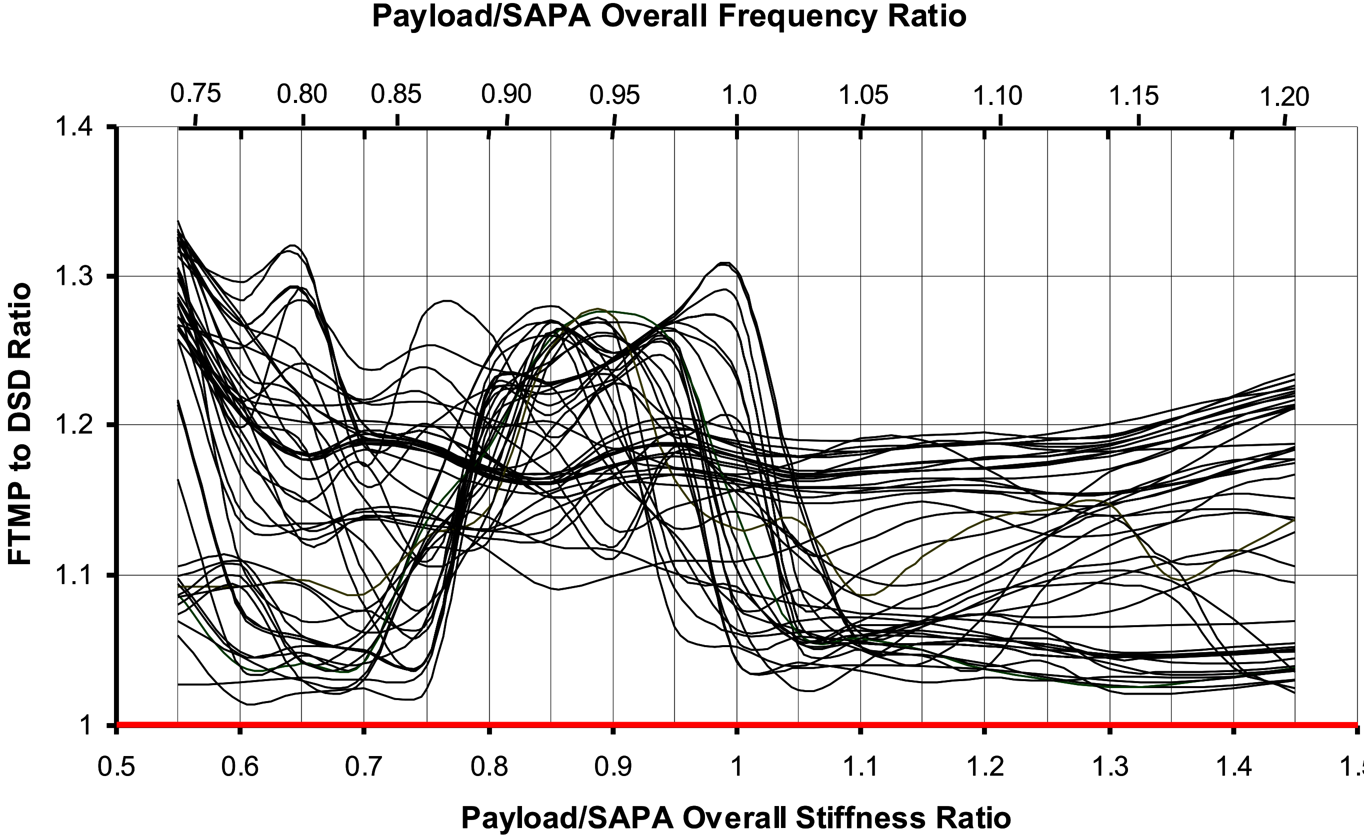
Impact of Damping Approximation - 50 Most "DSD to FTMP" Sensitive SOLAR Landing Internal Recoveries



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Concluding Remarks

- It is clear that detailed variational CLA is the most accurate and reliable risk mitigation exercise for assessing the impact of component parameter uncertainties

- The required schedules for traditional CLA tools have been a prohibitive factor in conducting variational CLAs
  - We often have to rely on uncertainty factors
    - Penalize all component response items
    - Fails to envelope highly sensitive responses

- ASD/CLAS – A significant value-added tool for our technical community
  - Significantly reduce risk, schedule, and cost
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