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SWOT Payload Sine Vibration Analysis Using Matlab

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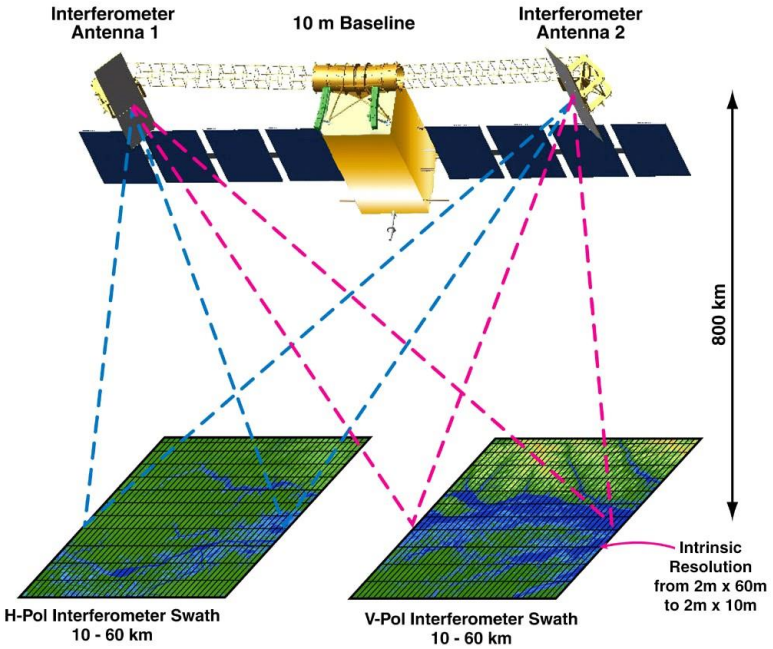
Overview

- SWOT Mission Overview
- Stowed Launch configuration
  - Load cases for launch survival
- SWOT Payload Sine Environment
- Payload Module Subsystem
- Matlab Tool for Sine Analysis
  - Output request and force/response limiting
  - Peak value calculation and post-processing
  - Examples using the tool
- Summary

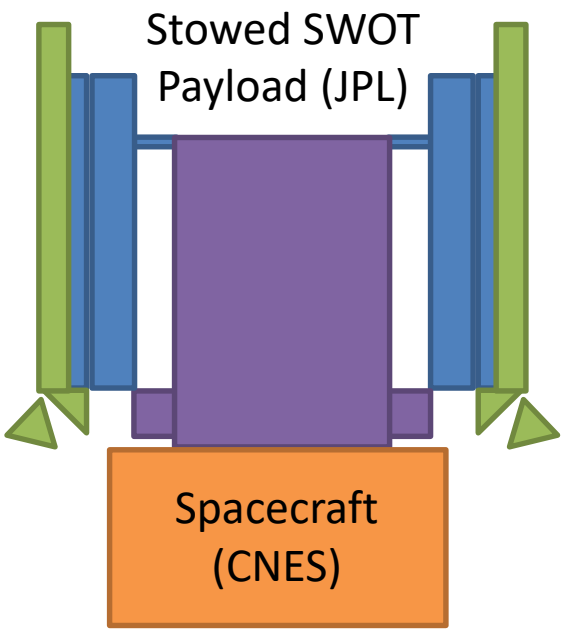
SWOT Mission Overview

- SWOT is Surface Water and Ocean Topography
- Collaboration between NASA and CNES
- Uses Ka-band radar interferometry to measure the depth of surface water across the Earth
- High resolution RF performance demands extremely strict performance requirements.
- RF support structure is designed for thermal stability



Stowed Launch Configuration

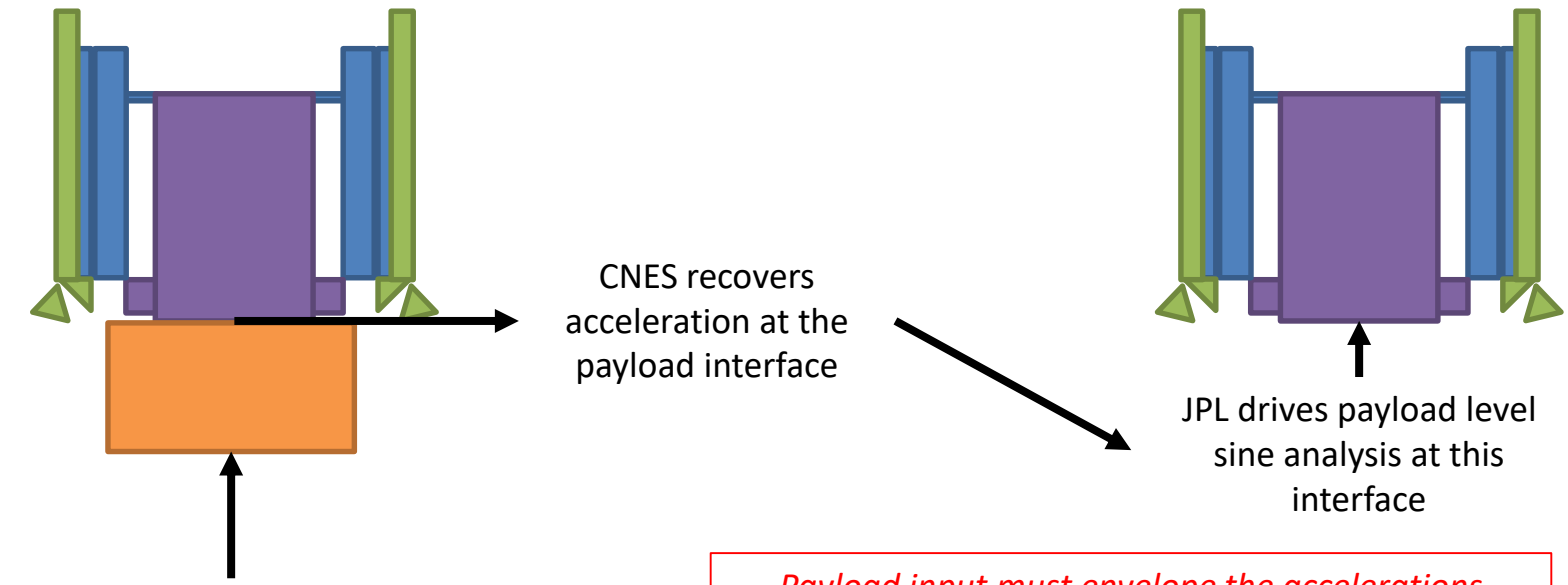
- SWOT Observatory reflectors, masts, and solar arrays are stowed during launch
  - Load paths include four hinges, several launch locks
- Three launch load cases
  - sine, random, MAC
- Sine load case is due to CNES partnership
  - Also driving load case for primary payload structure



Interface to launch vehicle

Development of Payload Sine Environment

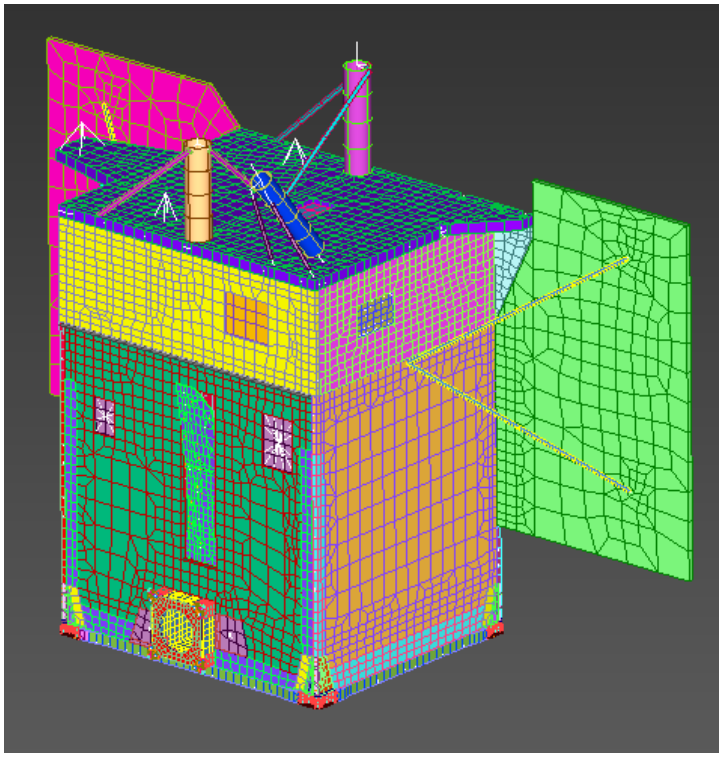
- Observatory sine vibration test to be performed by CNES
- Payload sine is intended to envelope loads from observatory sine
- But CNES doesn't share a FEM for the spacecraft



Payload input must envelope the accelerations recovered from observatory test, but force/response limiting must be used to prevent overtest

SWOT Payload Module

- Payload Module consists of SWOT primary structure
  - Honeycomb panels and metering structure
- Most subsystems and components on SWOT have local environments defined, but not the payload module
- The full payload level sine analysis must be run to evaluate configuration changes and recover stresses in the primary structure
- Difficult to perform stress analysis through sine vibration
- Available tools for sine analysis:
  - Derive an equivalent static load case (difficult for complex load paths)
  - Femap SA toolkit (cumbersome, no reduced models, other issues)
  - NX Simcenter (similar problems to SA toolkit)



Payload Module FEM

Matlab Tool for Sine Analysis

- No easy way to have NASTRAN output “peak” results from frequency response
- Solution: NASTRAN input/output files are text-based. Matlab can read in the results and calculate peak values for forces and stresses.
- Summary of capabilities:
  - Read in frequency-dependent results from NASTRAN punch file
  - Generate a notched input based on force/response limiting specification
  - Plot acceleration/force/stress versus frequency to determine which frequencies contribute to highest loads
  - Generate f06 file for viewing peak contours in post-processor
- Advantages:
  - Process a large amount of frequency-dependent data into a single file
  - Work directly with NASTRAN results from solution 111
  - Easier to set up and use than SA Toolkit or Simcenter
  - Allows rapid iterations of sine analysis
- Negatives:
  - NASTRAN output file with frequency-dependent data can grow very large
  - Requires user to be familiar with Matlab

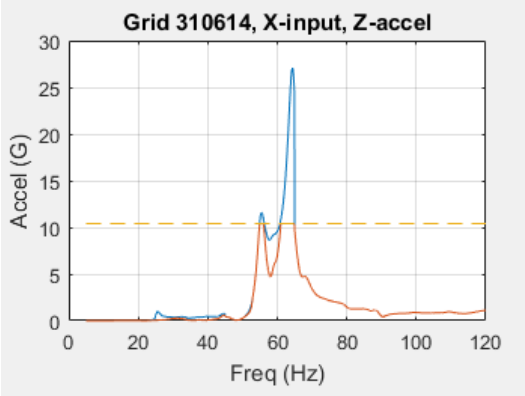
Matlab Tool – Raw Results and Notching

- Acceleration, force, and stress requests are added to NASTRAN case control
  - Request is FORCE(PUNCH,PHASE) = SET # [or ACCELERATION or STRESS]
  - Sets can be prepared easily with Femap or other pre-processor, much faster and easier than using XYPUNCH
  - Von mises stress from NX NASTRAN version 9 or newer is also supported
  - Compatibility:
    - Grid: acceleration and SPC force
    - Element force: CBUSH, CBAR, CBEAM, CBEND
    - Element stress: CBAR, CBEAM, CBEND, CQUAD4 (center or corner, also ply-by-ply laminates), CTRIA3 (center/corner), CHEXA, CPENTA, CTETRA
- Notching script to apply force/response limiting
  - Notching specification needs to be defined only once
  - Script will generate notched input, and can also scale results from punch file. This means that notching and force/stress requests can be done in a single NASTRAN run.

Sample stress request

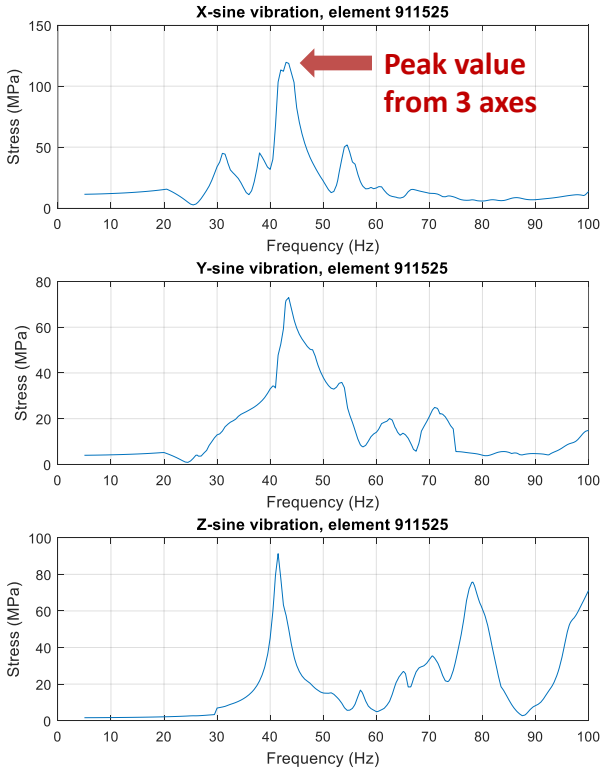
```
$ Stress request : limited subset request of tubes/brackets
SET 520 = 901744 THRU 901767,901969 THRU 902888,
    904350 THRU 904472,904883 THRU 904884,
    904888 THRU 904897,904906 THRU 904915,
    904948 THRU 904974,905306 THRU 905325,
    905332 THRU 905342,905344 THRU 905350,
    905356 THRU 905360,905362 THRU 905377,
    905382 THRU 905415,905420,905422 THRU 905424,
    905426 THRU 905428,905476 THRU 905557,
    905882 THRU 906593,906612,906623 THRU 906773,
    906775 THRU 906958,910243 THRU 910256,
    910264 THRU 910278,910360 THRU 910627,
    910631 THRU 910717,910841 THRU 910860,
    910992 THRU 911237,911241 THRU 911284,
    911287 THRU 911321,911525 THRU 912148,
    913400 THRU 913413,913682 THRU 913685,
    913701 THRU 913708,913730 THRU 913732,
    915910 THRU 915930,916271 THRU 916280
STRESS(PUNCH,PHASE,SORT2,CORNER) = 520
```

Acceleration response limiting



Matlab Tool – Peak Results and Output

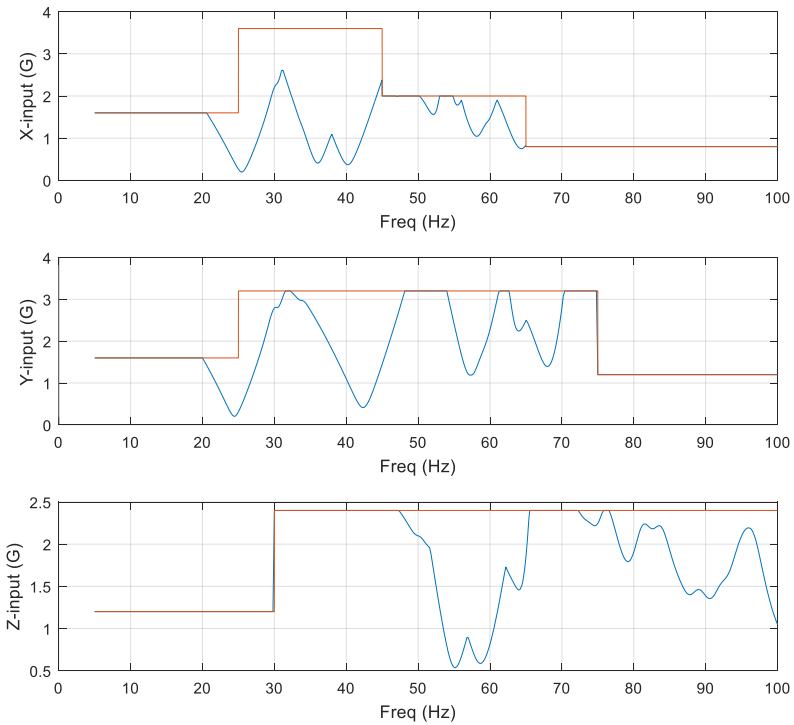
- Force/stress results are all in frequency domain
- Von mises stress can be calculated for plate and solid elements if it was not requested from NASTRAN
  - Von mises stresses are frequency-consistent values
- Combined axial stresses (tension + bending) are calculated for bar and beam elements
- For each force/stress component, maximum value is found across all phase, frequency, and input direction (X, Y, and Z inputs)
- Three-axis peak results are treated as a single static case and written to an f06 file for post-processing
- SWOT project also adds an extra load uncertainty factor of 20%, so results are very conservative



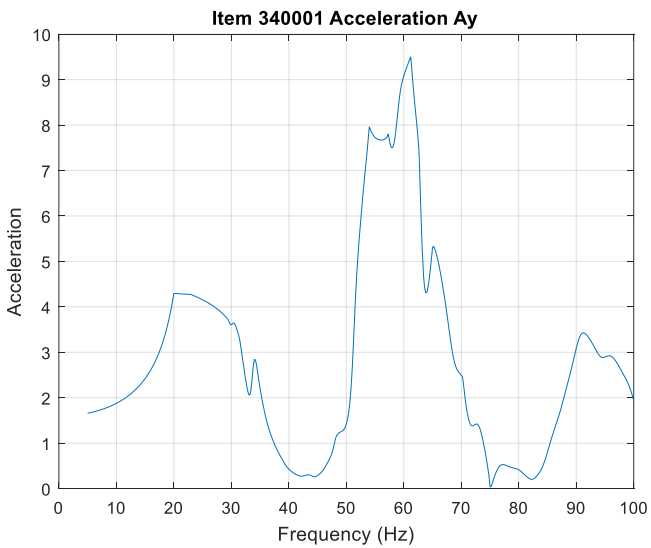
Examples of Sine Analysis

- Can also plot force/stress versus frequency
- Or plot responses with/without notching

Notched input profiles

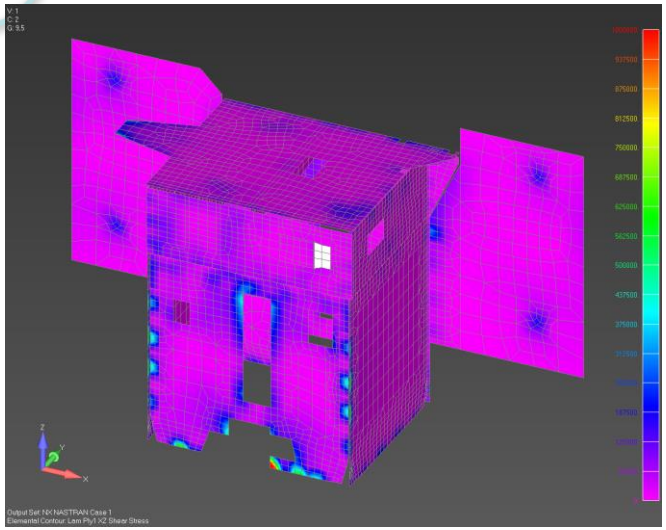


Grid acceleration

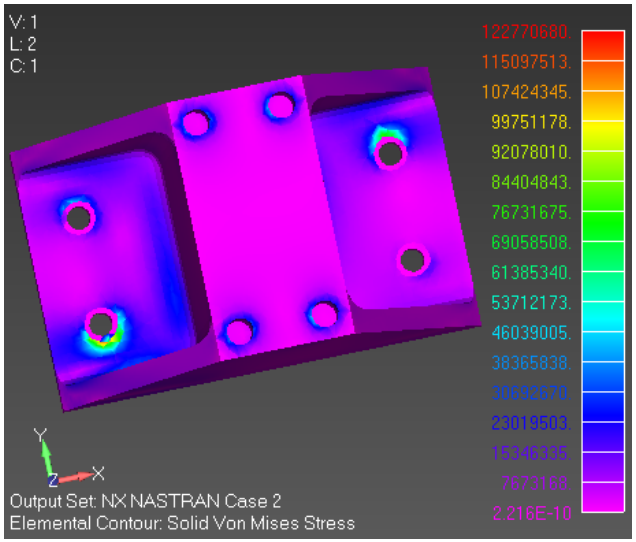


Examples of Sine Analysis

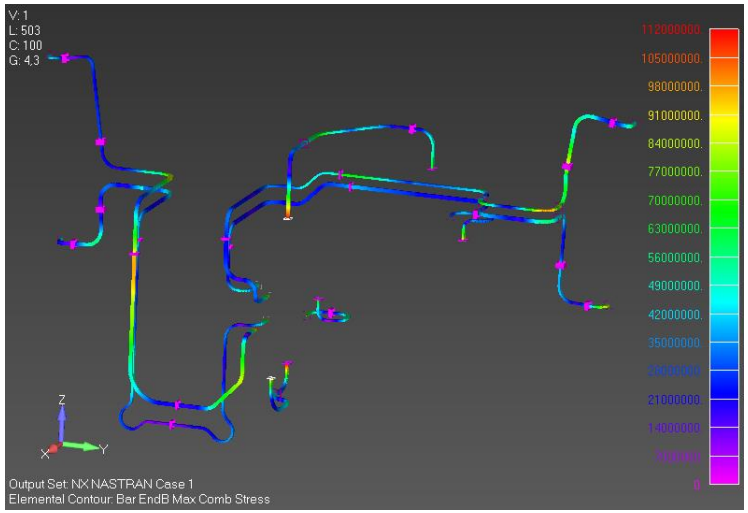
PCOMP element ply stresses



Solid von mises stress



Bar element max combined stress



Summary

- Matlab scripts have proved very useful for analysis on the payload module from PDR through CDR
- Analyst can iterate on the design and run sine analysis in a few hours
- SWOT Payload module has passed CDR and is approaching MRR
- Notching script is easily editable to be compatible with force/response limiting specification from other projects
- Punch file reader is easily extensible to add more element types for force and stress requests
- Scripts could be improved greatly with a GUI for better usability