Open Source Satellite Community Meetup

KISPE Optimum Satellite Design

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Head of Advanced Simulation

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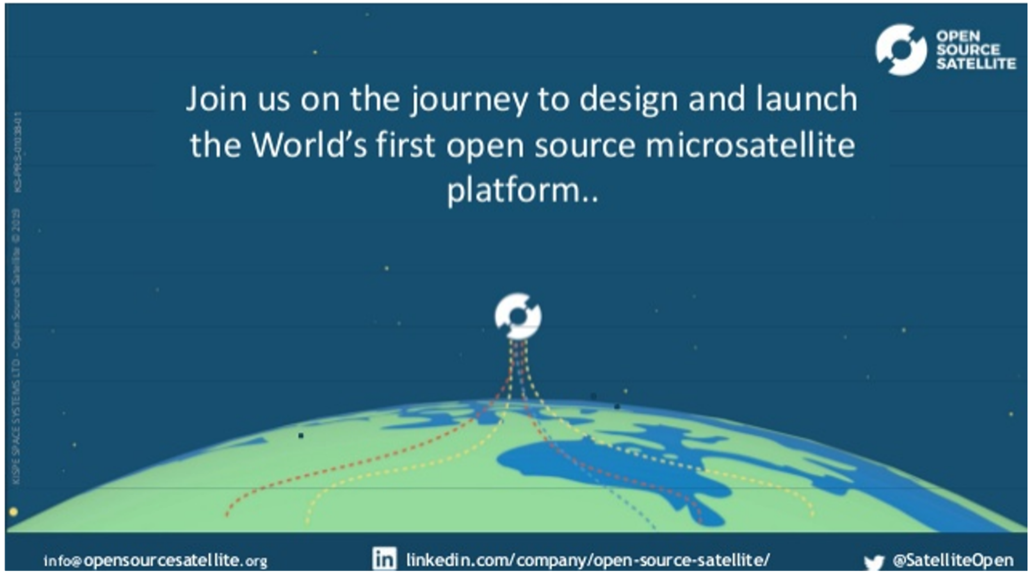
Head of Future Programmes

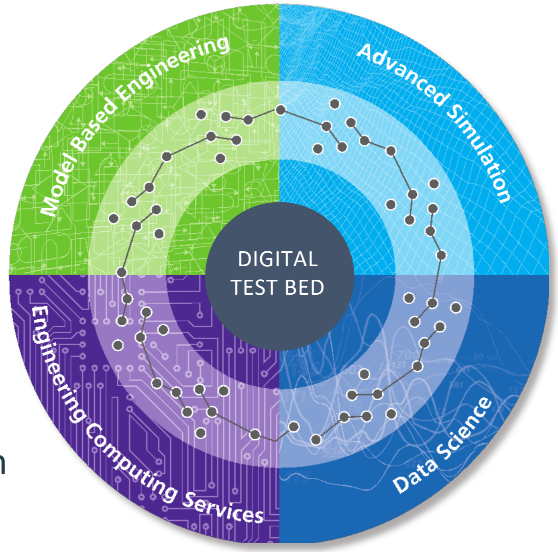
Agenda

- Introductions
- CFMS, DETI and DAWS
- Problem Description
- Finite Element Analysis
- Process Automation
- Optimisation Targets
- Risks and Future Steps
- Next Steps



CFMS—Centre for Modelling and Simulation

- A not-for-profit digital engineering consultancy based in the Bristol & Bath Science Park
- We believe that Digital Engineering is the only approach able to create solutions that meet today's challenges, including those of reaching net zero
- CFMS improves industrial productivity through the application of digital innovation to engineering challenges



Model Based Engineering – Construction of architectures for digital twins

Advanced Simulation – Mathematical modelling to answer fundamental questions

Data Science – Applying AI methods to reduce cost and optimise performance

Engineering Computing Services – HPC & IT Labs: a secure and agile testing platform

- We maintain neutrality, evaluating & maturing the best digital solutions for our customers in multiple sectors

DETI—Digital Engineering Technology & Innovation

National Composites Centre
cfms
Catapult Digital
UWE Bristol
University of Bristol
University of Bath

+

West of England Combined Authority

2 years

£8.85m

= DETI
DIGITAL ENGINEERING TECHNOLOGY & INNOVATION

Enabling Capabilities
Establishing digital domain expertise, core reusable technology & infrastructure to accelerate the shift to digital

Proofs of Concept
Sector agnostic projects to tackle barriers to digital transformation and investigate return on investment

Skills & Workforce Programme
A comprehensive skills and development programme to ensure the current and future workforce is digital-ready

DETI Seminars & Workshops

DIGITAL ENGINEERING TECHNOLOGY & INNOVATION

- UWE are holding some inclusivity events that might be of interest to today's audience
- Listening Workshops on the "*Hopes and Challenges for Under-Represented People in Engineering*"
    - **23rd June 13:30-14:30** Women (International Women & Engineering Day)
    - **6th July 13:30-14:30** Global Majority (Black, Asian and Ethnic Minority)
    - Sign up: https://uwe.eu.qualtrics.com/jfe/form/SV_8oBhyQg9Mvhlrn0
- Seminar, "*Inclusive Digital Engineering – What Happens Next?*"
    - Results from the Listening Workshops above (and a past Neurodiversity one)
    - **13th July 11:00-12:30**
    - Sign up: https://uwe.eu.qualtrics.com/jfe/form/SV_1LdRF5e4UWH6aHQ
- Please join in and help UWE with their valuable research

DAWS—Development of Advanced Wing Solutions

- The DAWS consortium is developing advanced wing designs such as folding wing tips and aero-elastic hinges
  - ATI funded £9 million; Industry funded £9 million
  - 3 year programme

- CFMS is studying
  - Automatic structure generation and optimisation
  - AI methods for data driven rapid design space exploration for multidisciplinary conceptual design optimisation
  - Deep Learning techniques for Natural Language Processing of published scientific documents for knowledge extraction and sharing

AIRBUS

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ITI a wipro company

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University of BRISTOL

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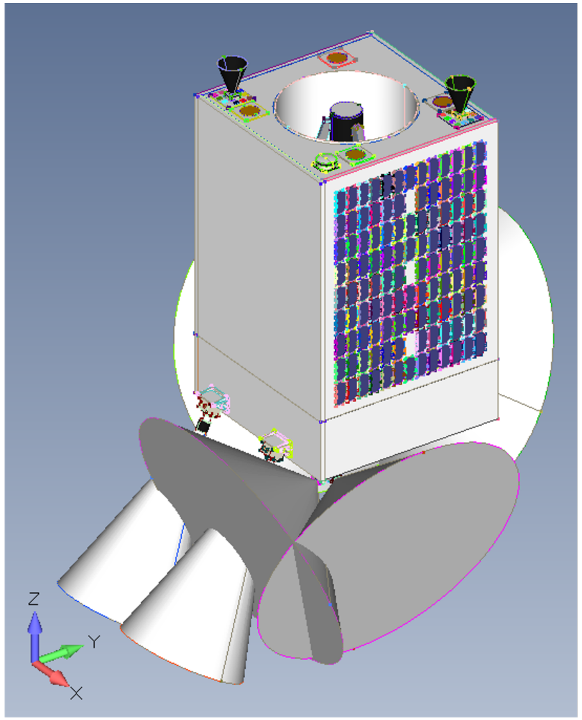
UNIVERSITY OF Southampton

Problem Description

Technical Objective Summary

To optimise the structure of KISPE Space's initial OSSAT concept design for multiple objectives



Variables

- Satellite materials
- Satellite geometry
- Equipment positions/layouts (including main payload)

Constraints

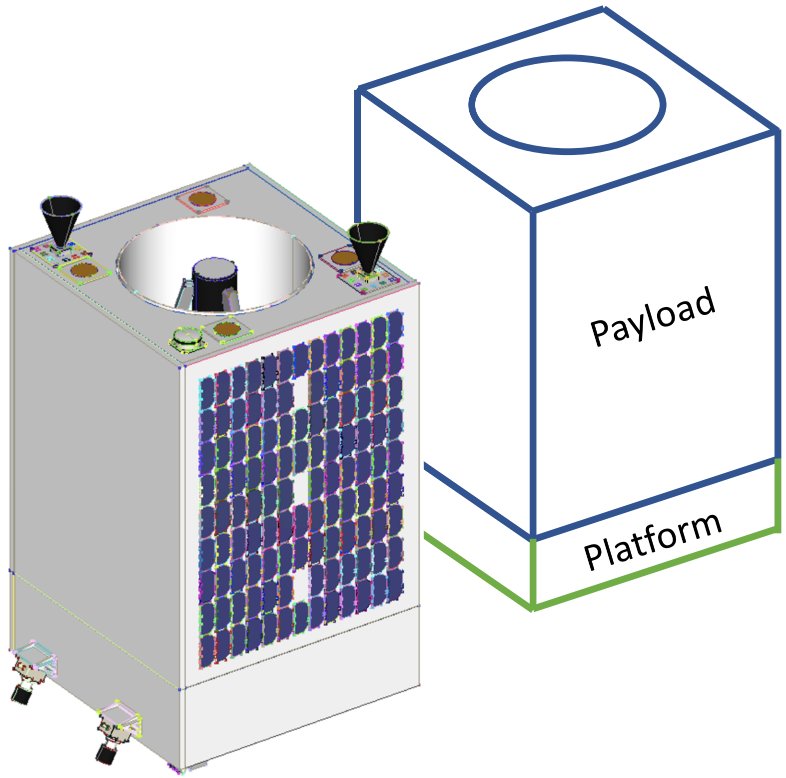
- Structure must withstand all loads seen through transport, launch & operation
- Multiple launchers to be considered
- Satellite centre of gravity must be within predefined volume

CFMS Tasks

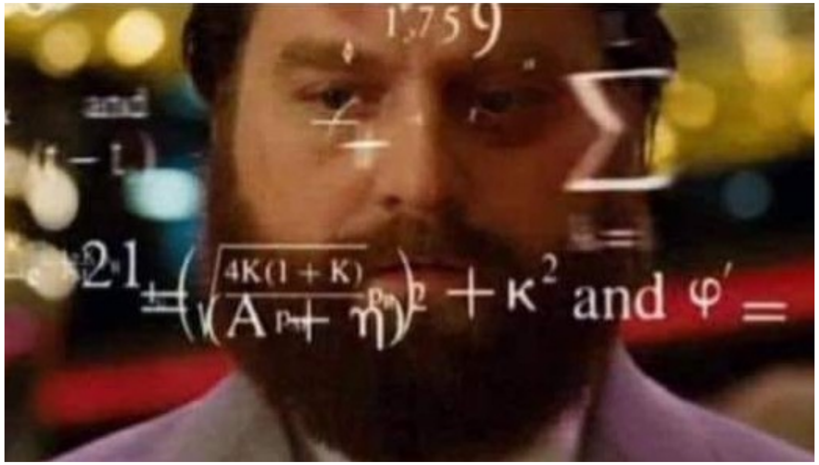
- Develop a method to evaluate a commonised structure with the intention of reducing engineering recurring costs
- Automate model creation and optimization process to allow for the consideration of a wide range of configurations (e.g. payload, rocket type, CG position, etc)

Project steps:

1. Simplify/idealize CAD model
2. Create dynamic loading input cards (shock, frequency response and random response)
3. Automation of model creation
4. Multi-Objective Optimization of OSSAT structure

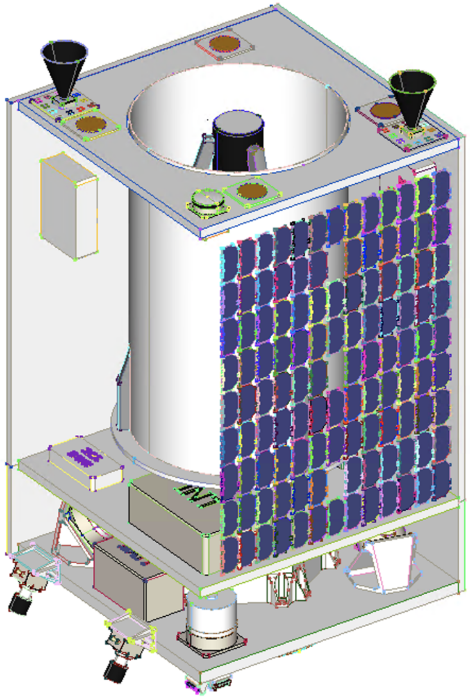


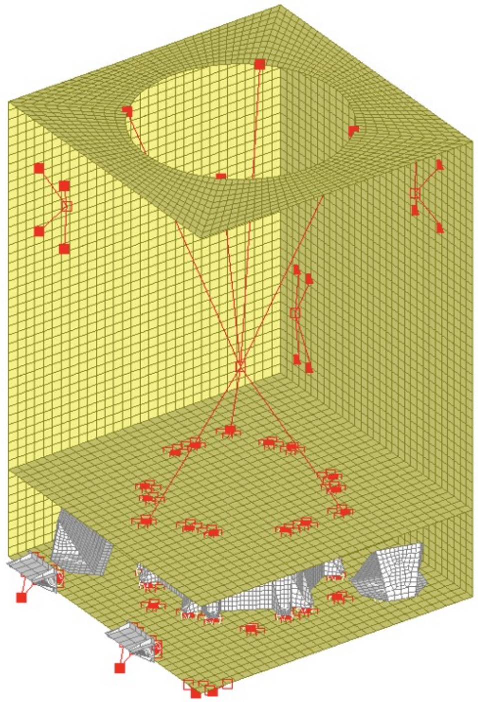
Complexity of Optimisation



Finite Elements Analysis

Idealisation of OSSAT CAD





< 15,000 elements

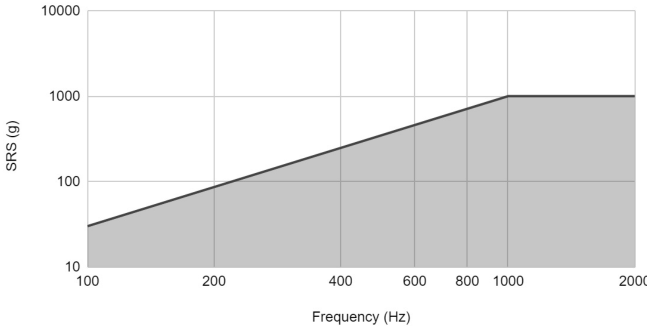
Dynamic Analysis of OSSAT Structure

- OSSAT structure was considered under shock, frequency response and random response analysis
- Excitation introduced through supporting elements
- Launch and transportation (road, rail, sea, air) loading input

Shock Analysis

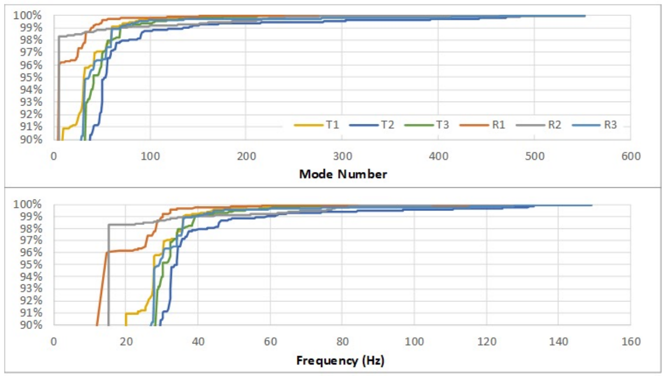
Sudden enforced acceleration (e.g. 30 g load at 100 Hz, 5 ms)

SpaceX: Payload adapter-induced shock at the spacecraft separation plane (P95/P50)



Frequency Response

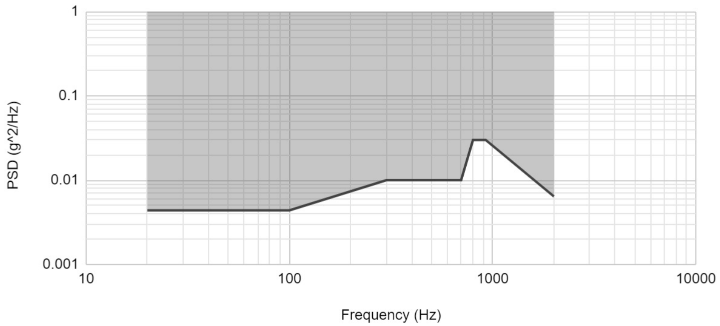
Structure subjected to 1 g load, over a range of frequencies



Random Response

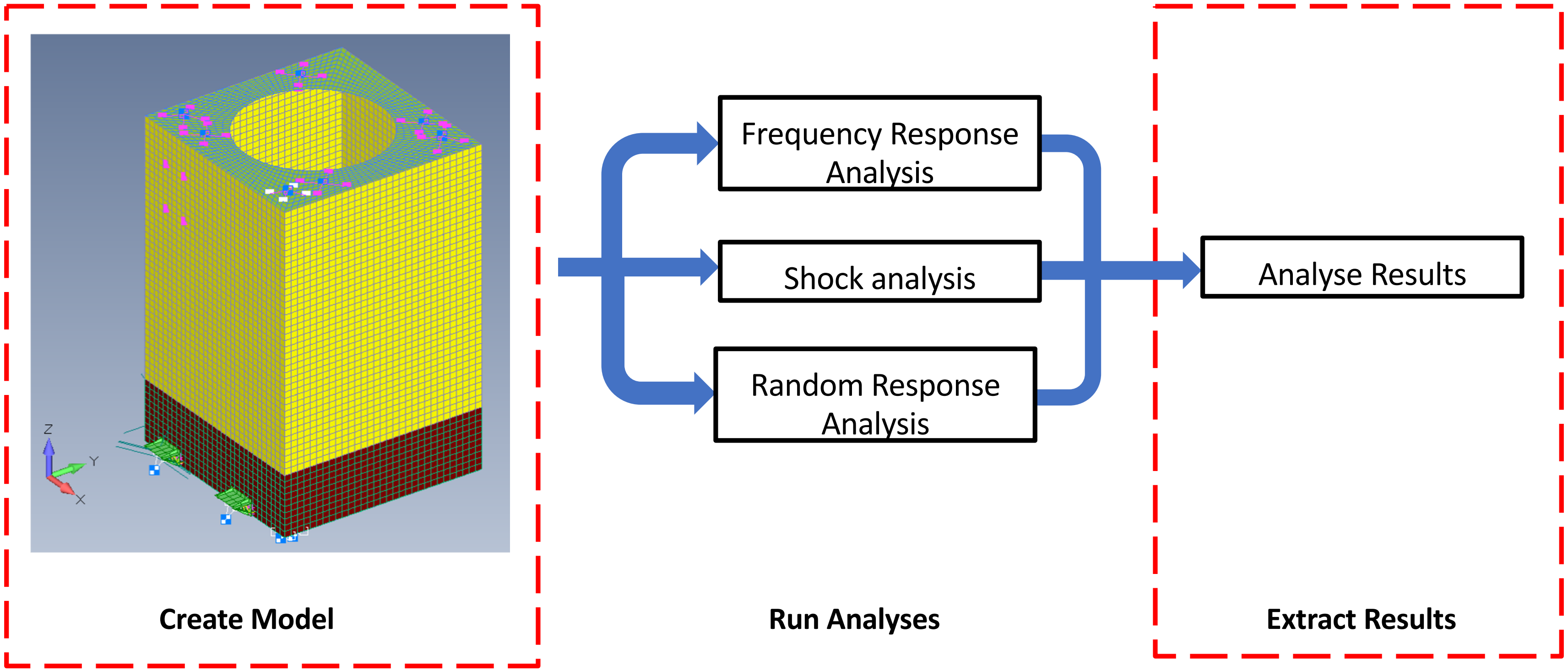
Structure subjected to 1 g load, where the vibration is described in a statistical sense

Figure 4-9: Falcon 9/Heavy Payload Vibration MPE, (P95/P50), 5.13 GRMS vs Frequency (Hz)



Process Automation

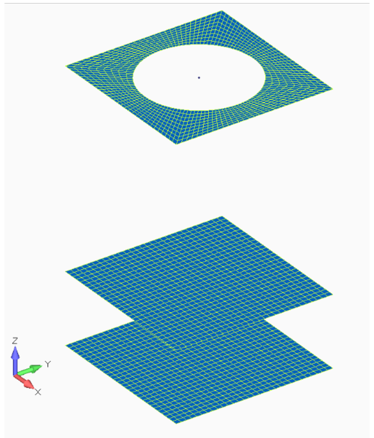
Process Automation

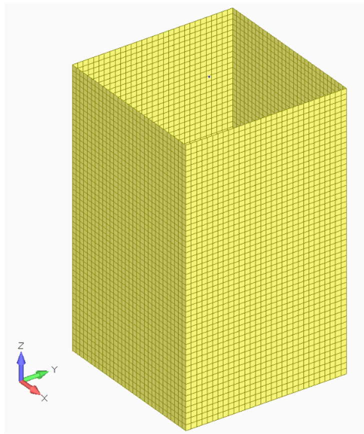


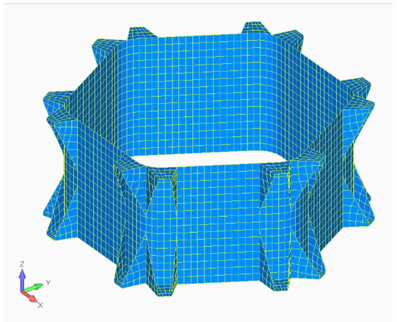
Automate FEM Creation

General approach

- Use Python and our own in-house code to create the NASTRAN/ Femap input files of the satellite
- Using in-house code instead of NASTRAN API
- User inputs parameters describing key geometry sizes
- Parameter values will be determined by design of experiment (DoE) in the final optimisation



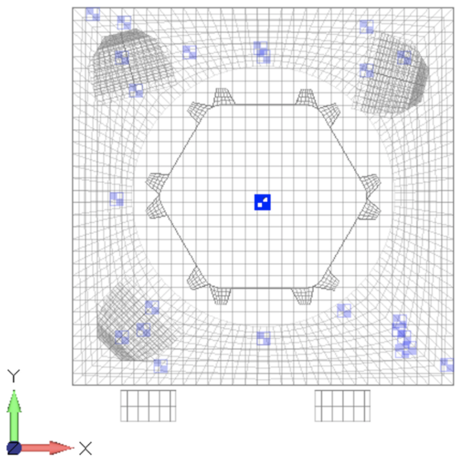


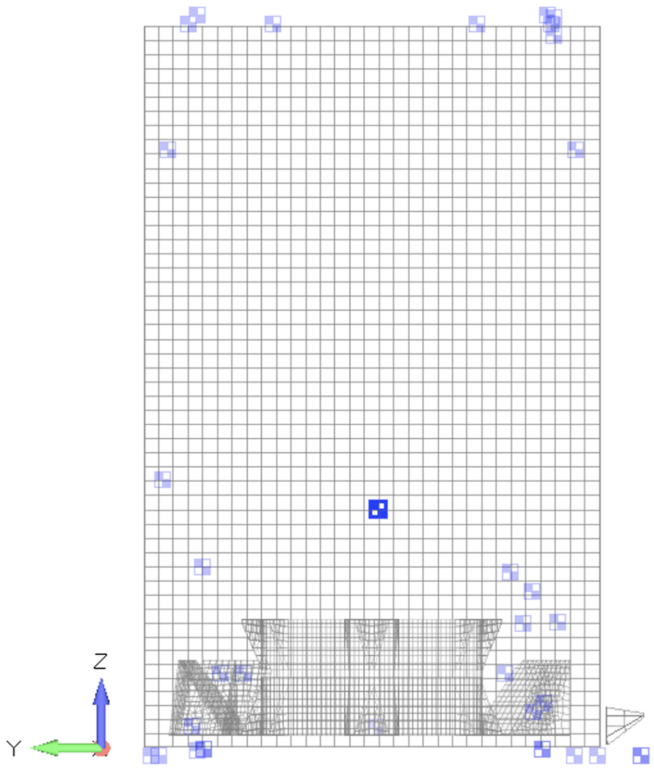


Automated FEM Creation – Key Features

Centre of Gravity Calculations

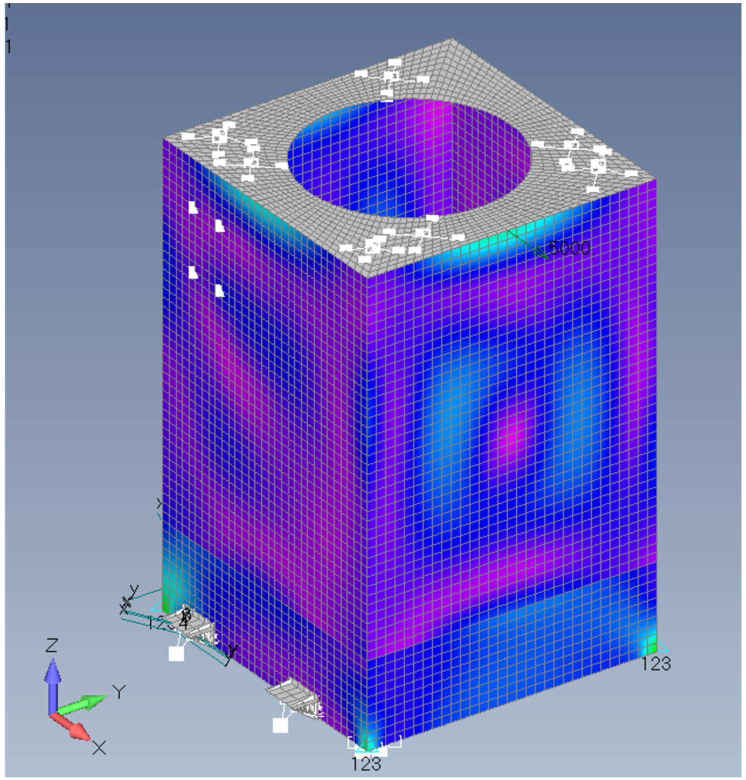
- Implemented a framework to determine the centre of gravity of the model before importing into Femap/ NASTRAN
- Saves time by only advancing valid models for further analysis





Automated FEM Creation – Key Features

To assess the performance of each satellite, we need the output of three main analyses: Frequency Response, Random Response, and Shock Analysis. These differ from the usual static structural analyses for which our code was designed



Core Challenges

- Output is formatted differently
- Files sizes (>10 GB) make existing approach impractical
- Less common analysis types:
  - Differs from DAWS work
  - PyNastran Issues

Solutions

- Refine output to only relevant data
- Use new file format to make data more parsable

Optimisation

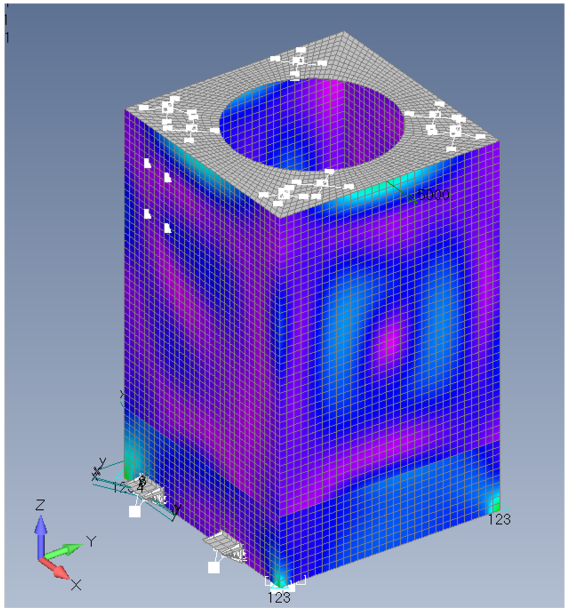
- Optimisation will be done using a CFMS-developed toolkit
- PARSIT (**PAR**ameter **S**pace **I**nvestigation **T**oolkit) is a multi-objective optimiser (MOO)
- This has been used for simpler problems of a similar nature

Variables	Constants	Constraints	Objectives
Height/radius of inner hexagon structure	Loading	Must survive all load cases without failure	Minimum weight
Materials selection	Outer satellite geometry (*for now*)	Centre of gravity must be within predefined region	Maximum payload volume
Composite layup of Satellite panels	Equipment positions (*for now*)		Cost (*eventually*)
Bracket thicknesses/materials			Radiation shielding (*eventually*)

Risks and Future Steps

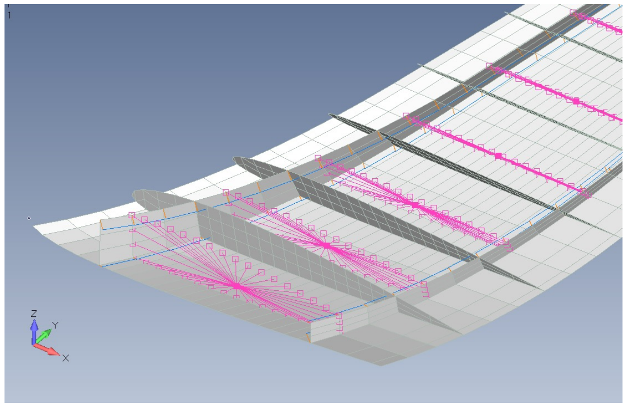
Risks

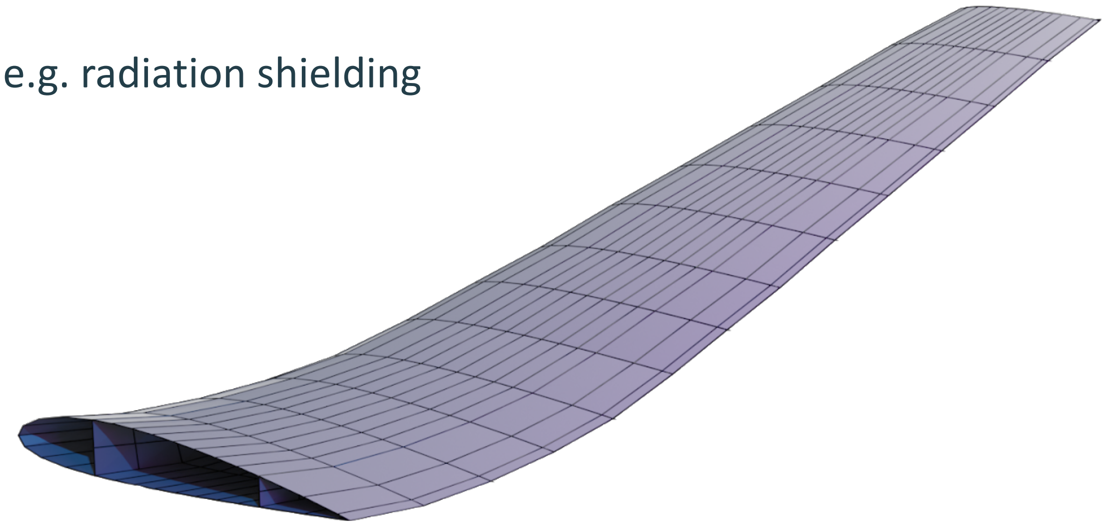
- Optimisation is a compromise and can introduce weak points (metastable equilibrium)
- Quality of initial data is fundamental
- Strong computational power required (HPC)
- Large storage for data
- One size may not fit all



Future Steps

- Look into broadband frequency approach for linear frequency response analyse
- Employ CFMS Data Science expertise (AI) for mass distribution trends
- Introduction of additional input/variables (e.g. radiation shielding modelling)
- Exchange tools with DAWS



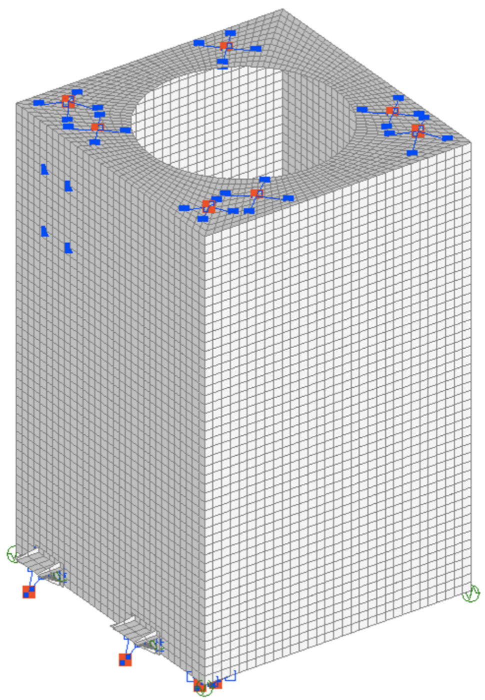


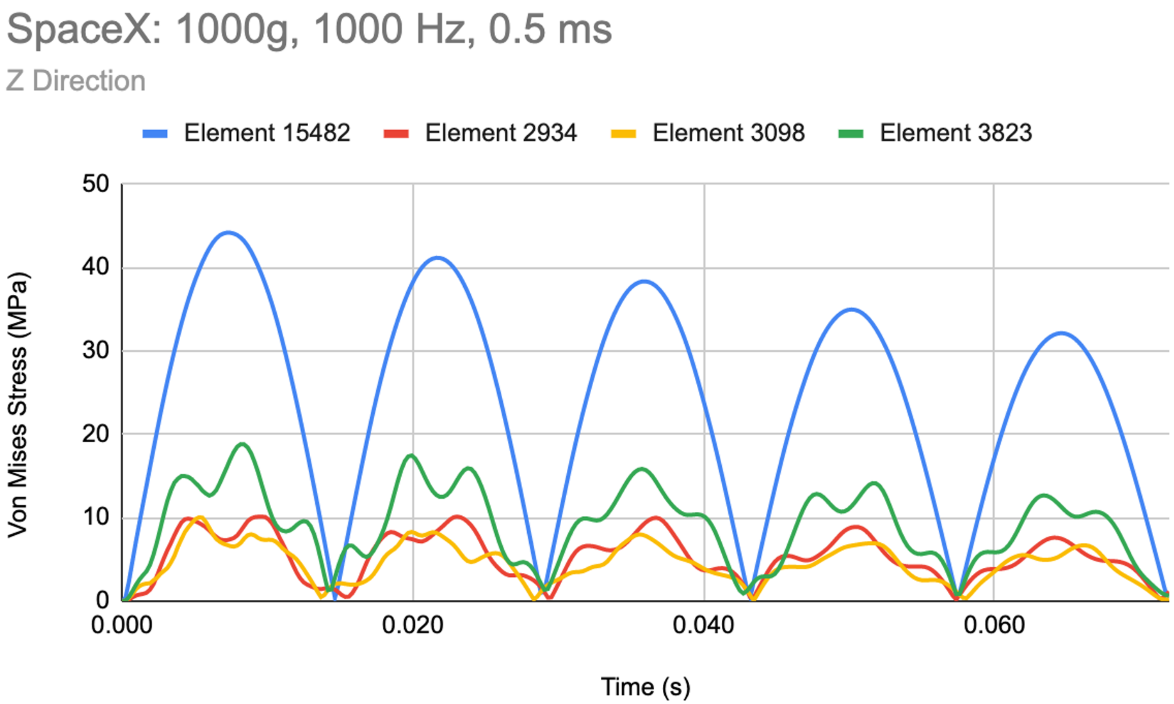
Q&A

Additional Slides

Dynamic Analysis of OSSAT Structure /1

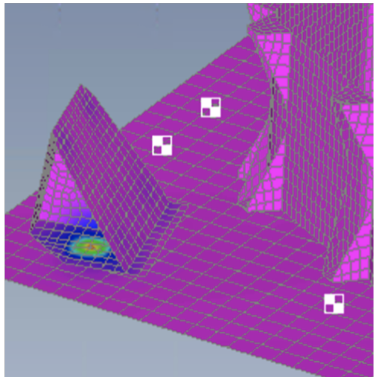
Shock Analysis

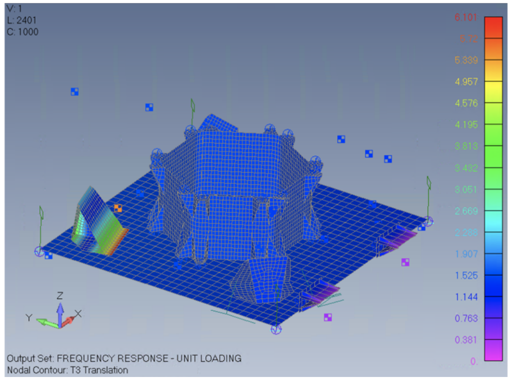




Dynamic Analysis of OSSAT Structure /2

- **Frequency Response Analysis**
  - Structure is analysed at a 1g enforced acceleration over a set of pre-defined frequencies:
    - Informed by normal modes analysis
    - Industry standard frequencies for transportation by road, rail, sea and air





Von Mises Stress (left) and Nodal Translation (right) at 36 Hz

Transportation by road

Mexico City earthquake, 1985

Dynamic Analysis of OSSAT Structure /3

Random Response Analysis

Derived from flight data

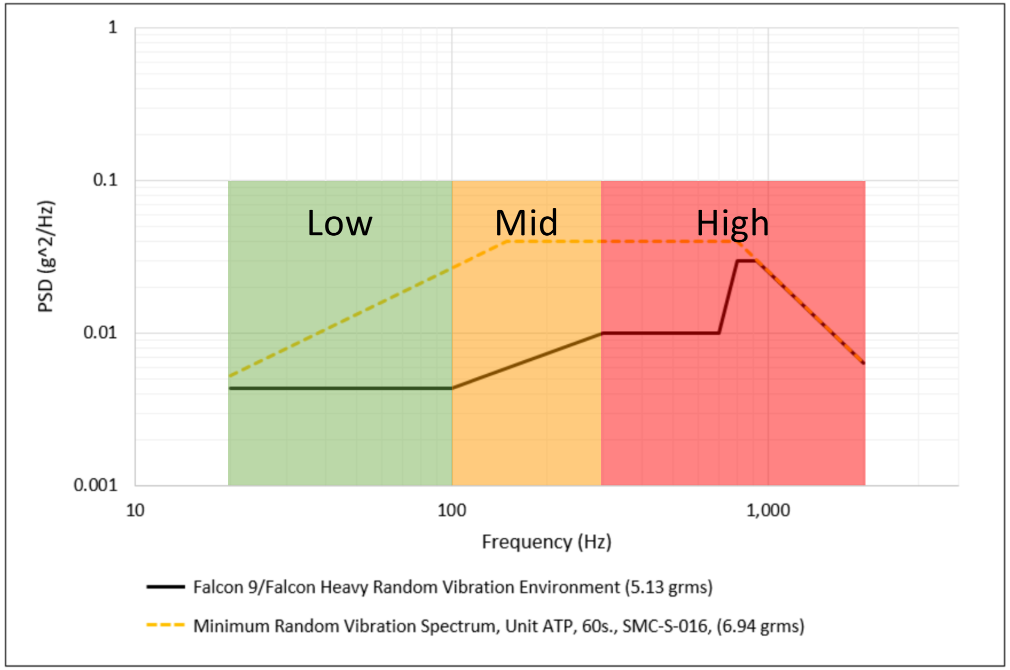


Figure 4-9: Falcon 9/Heavy random vibration maximum predicted environment (P95/50) at top of PAF [5.13 GRMS]

Low: excitations driven by global vehicle motion
Mid: excitation due to aeroelastics (acoustic and aero buffet)
High: excitation due to structure borne vibrations

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