Understanding Space Shuttle Structural Dynamics

George James

NASA-Johnson Space Center

Technical Manager - Space Shuttle Loads & Dynamics Panel
Structures & Dynamics Branch (ES2) - NASA-JSC

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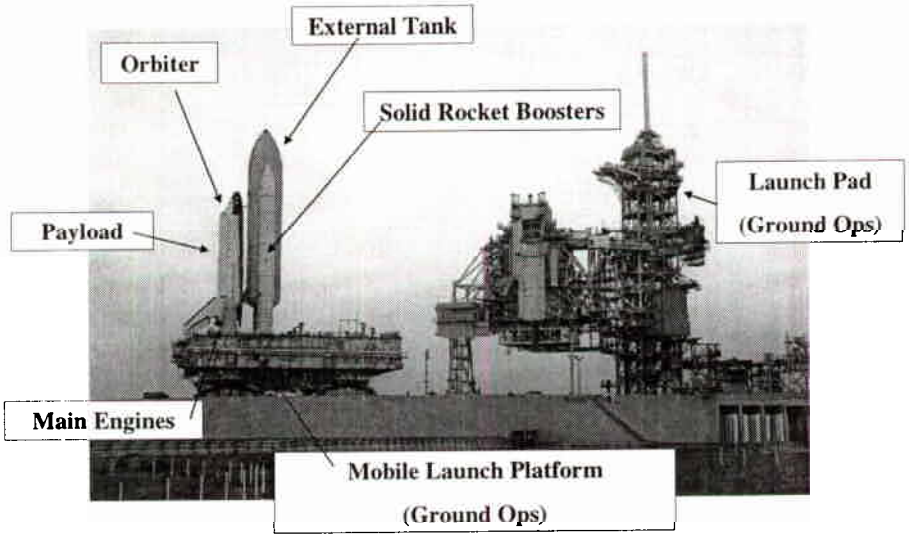
What Am I Going to Talk About?

1. What is the Space Shuttle.
2. What are Structural Dynamics and Why Do We want to Understand Them.
3. Explain how we have worked to understand the dynamics in the past, today, and in the future.

What Is the Space Shuttle?



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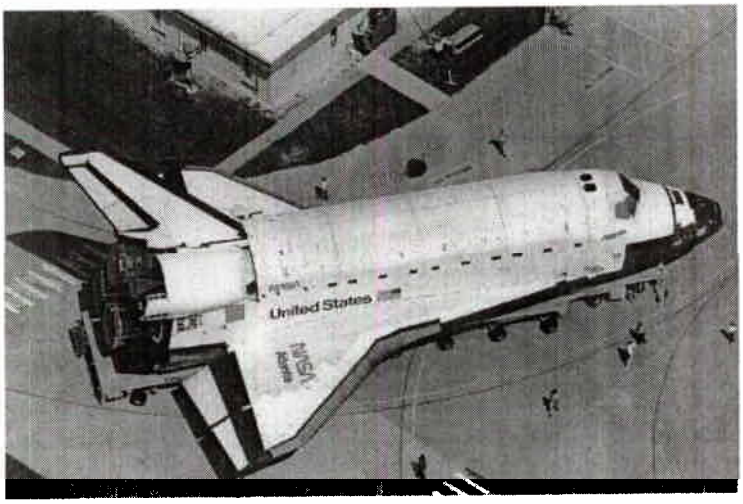
Space Shuttle Orbiter



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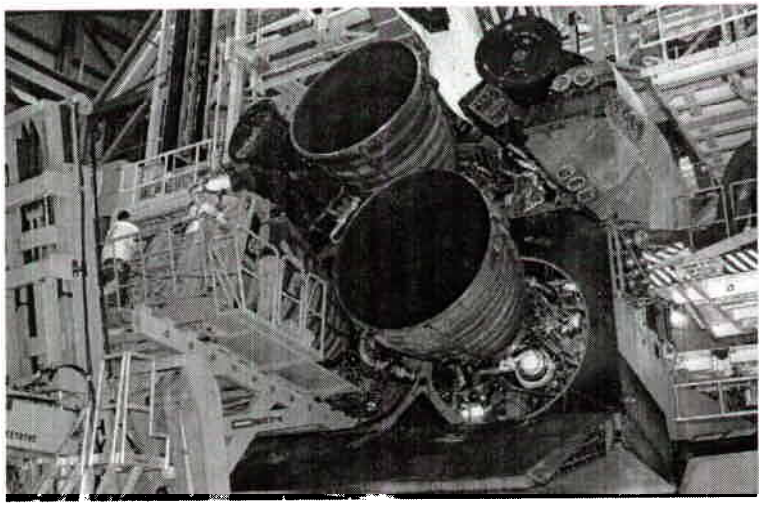
Space Shuttle Main Engines (SSME)



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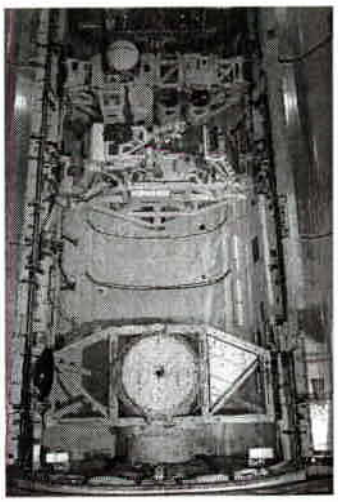
Space Shuttle Payloads



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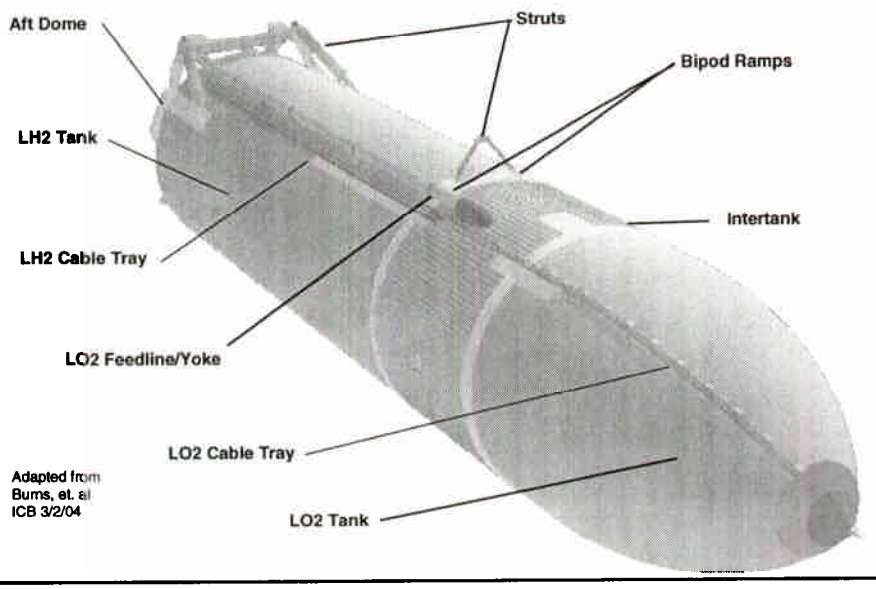
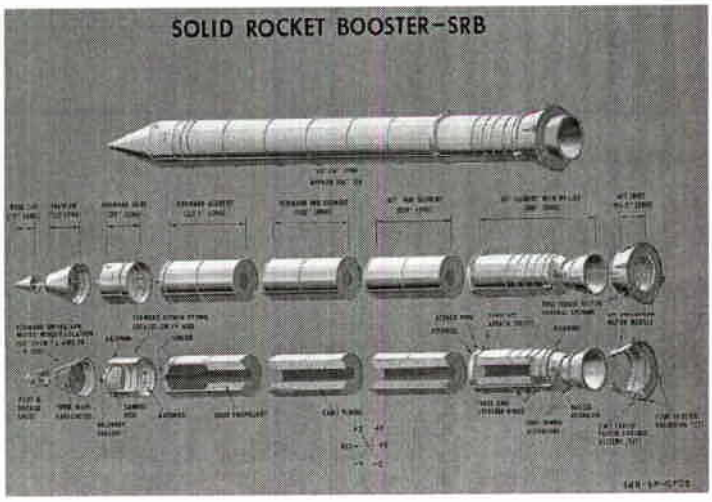
Space Shuttle External Tank (ET)



Adapted from
Burns, et. al
ICB 3/2/04

Space Shuttle Solid Rocket Boosters (SRB)



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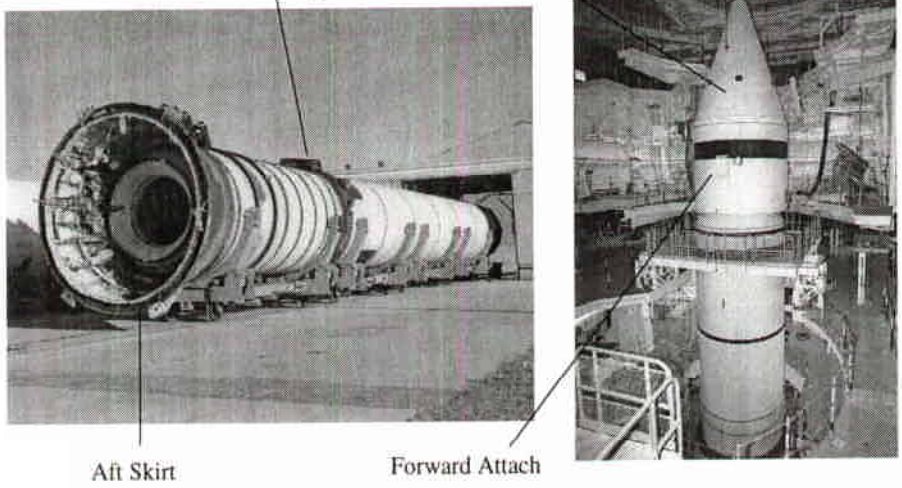
Space Shuttle Solid Rocket Booster (SRB)



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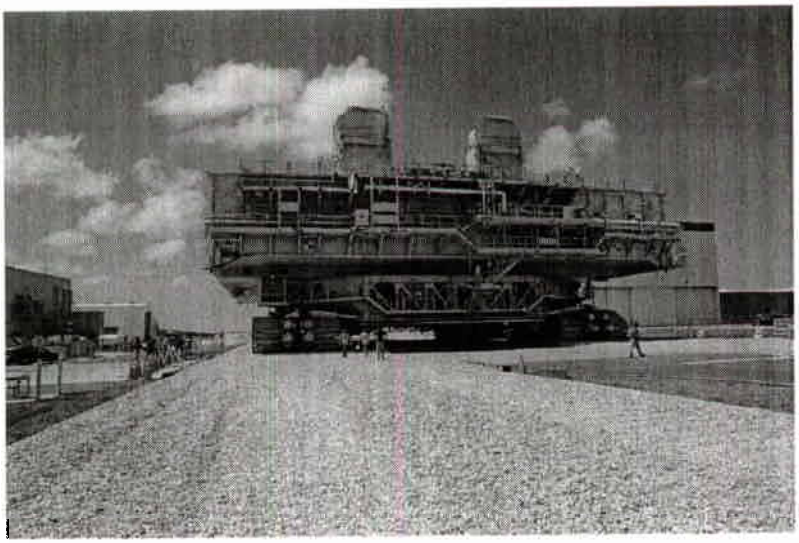
Space Shuttle Mobile Launch Platform (MLP)



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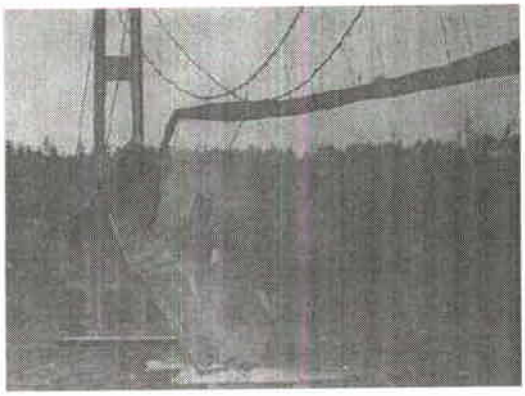
What is Structural Dynamics?

All structures will vibrate at certain frequencies:



The Tacoma Narrows Bridge is the classic example of structure dynamics

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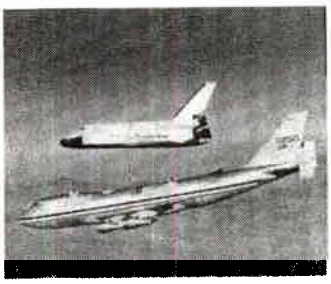
Why Understand the Dynamics of the Shuttle?

1. To make sure it can survive.
2. To control it.
3. To make sure that it can perform its mission.
4. To keep it from aging prematurely.



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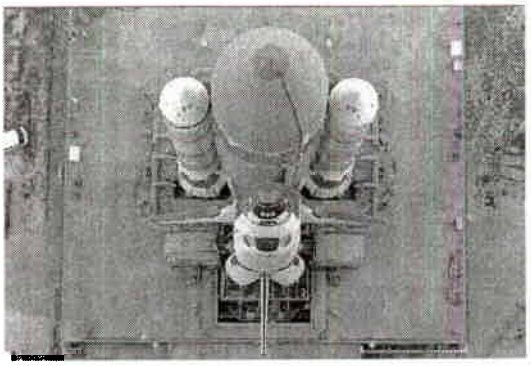
Why is the Space Shuttle Complicated?

1. It is a parallel stack.



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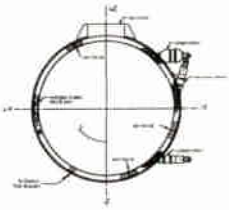
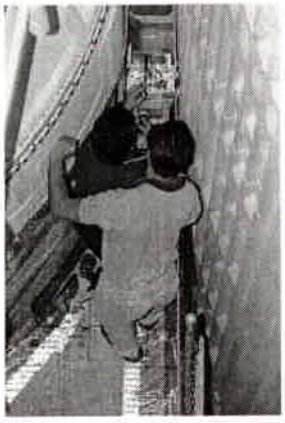
Why is the Space Shuttle Complicated?

2. Complicated Element Mating





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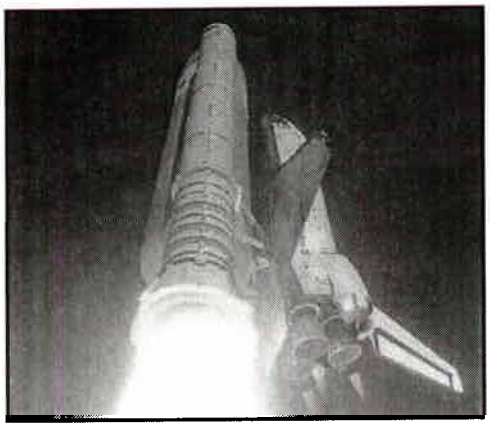
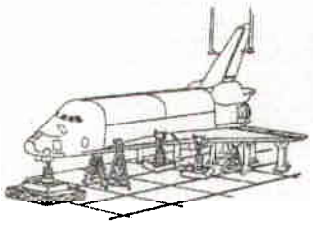
Why is the Space Shuttle Complicated?

3. Millions of pounds of thrust.
4. Wings & Tail
5. Complicated Forces



How Do We Understand the Structural Dynamics of the Space Shuttle?

1. Model it.
2. Test it.
3. Fly it.



Modeling Structural Dynamics

Any complicated structure in a real environment needs to have a mathematical model to predict the response:

$$M\ddot{x} + C\dot{x} + Kx = F$$

M is the mass distribution;

C is the energy dissipation (damping);

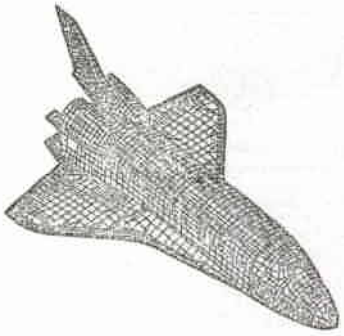
K is the stiffness distribution;

F are the applied forces;

x is the displacement distribution;

$\dot{x}$ is the velocity distribution; and

$\ddot{x}$ is the acceleration distribution.



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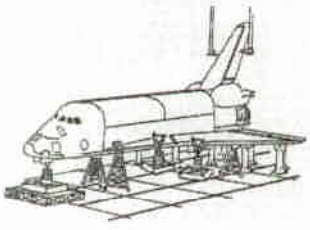
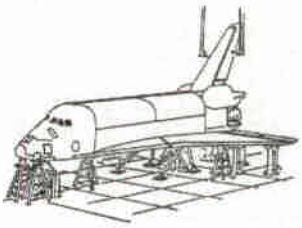
Early Structural Dynamics Tests

We tested the Orbiter to check the models.



Launch Configuration



Landing Configuration

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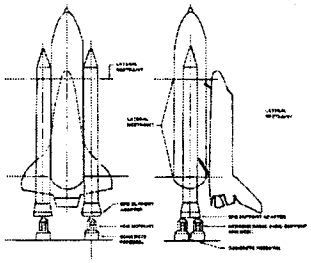
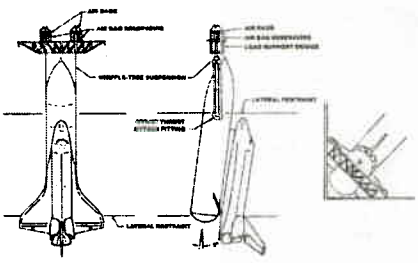
Early Structural Dynamics Tests

We put all of the elements together to make sure we knew how the whole system worked



Launch Configuration



Ascent Configuration

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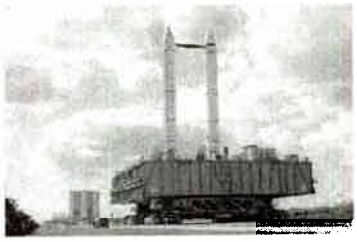
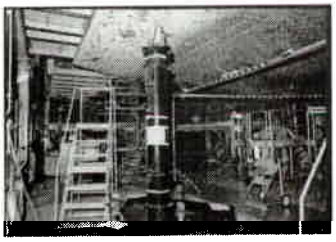
On-Going Structural Dynamics Tests

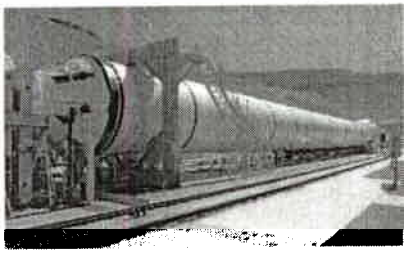


Roll-Out Tests



Shuttle Modal Inspection System (SMIS)

Engineering Test Motor (ETM) - 3



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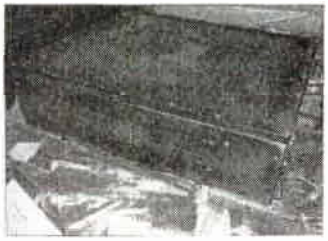
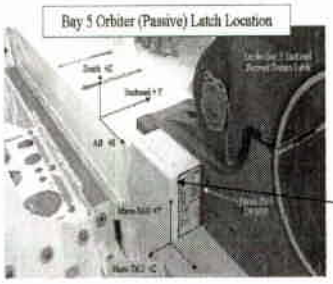
Flight Data



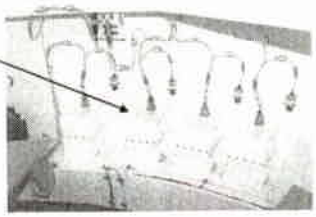
Modular Auxiliary Data System (MADS)

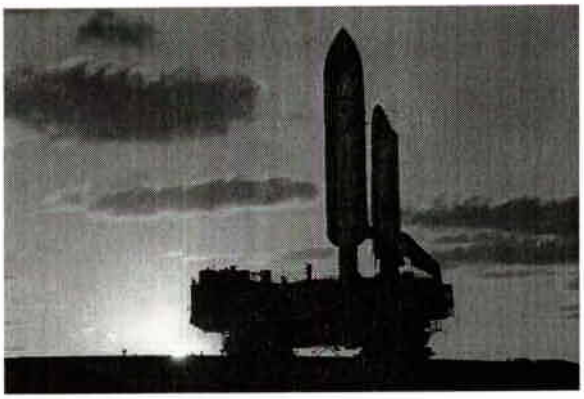
Stand-Alone Acceleration Monitoring Device (SAAMD)



Micro Triaxial Acceleration Unit (Micro-TAU)

Enhanced Data Acquisition System (EDAS)





Conclusions

1. **The Space Shuttle has pushed technology for 30 years.**
2. **The system is complicated enough that we are still learning.**
3. **New structural technologies are still flowing from the Shuttle.**